ANNALES

de la
SOCIÉTÉ SUISSE DE ZOOLOGIE
et du
MUSÉUM D'HISTOIRE NATURELLE
de la Ville de Genève

tome 117
fascicule 4
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# REVUE SUISSE DE ZOOLOGIE

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## TOME 117—FASCICULE 4

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Le comité soumet chaque manuscrit pour évaluation à des experts d'institutions suisses ou étrangères selon le sujet étudié.

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# Global checklist of pseudoscorpions (Arachnida) found in birds' nests

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**Global checklist of pseudoscorpions (Arachnida) found in birds' nests.** - A compilation of the information on pseudoscorpions recorded from birds' nests is presented. Species and families of birds, and specimens, species and families of pseudoscorpions involved worldwide are given. 14 families (63 genera with 85 species) of Pseudoscorpiones were found in birds' nests, of which the Chernetidae is ranked first, with 22 genera and 35 species. Only 45 families of birds have been recorded as hosts worldwide, represented by a total of 98 species and a certain number of unidentified taxa. Geographical origin of these records reflects collecting efforts of individuals and gives no precise indication on the biological association between these two groups.

**Keywords:** Ecology - behaviour - phoresy - host association.

## INTRODUCTION

The arachnid order Pseudoscorpiones, commonly known as pseudoscorpions, false scorpions, or book scorpions, comprise about 3.3% of the described arachnids, with 3 385 known species (Harvey, 2009). Pseudoscorpions are small (typically less than 4 mm in length) predacious arachnids, feeding upon small invertebrates (e.g., mites, springtails, various flies and gnats, ants, insect larvae, and occasionally small caterpillars). The general ecology of the group is poorly known; the most intensive studies on tropical pseudoscorpions have been carried out in the Manaus Amazon region, under the guidance of the late Professor J. Adis (Plön, Germany) (e.g. Adis, 1979, 1992; Adis & Mahnert, 1985, 1990). They live in leaf litter, under rocks, in compost piles, under bark and in decaying wood, in caves, and in various invertebrate and vertebrate nests (Beier, 1948, 1963b; Weygoldt, 1969).

No answer can be given to the question whether pseudoscorpions are arriving accidentally in the nests, if they are regular visitors, or if nests represent their favoured habitat. Beier (1948) had in his compilation enumerated 12 species found in birds' nests or on birds, citing two species as living exclusively in this biotope: *Diplotemnus insularis* Chamberlin and *Hesperochernes montanus* Chamberlin, but all these conclusions were based on isolated findings. An exhaustive ecological study had been

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carried out by Nordberg (1936) on the nidicolous arthropods of bird's nests in Finland (mainly from Aland, a few nests also from Tvärminne and Helsingfors), but unfortunately only three pseudoscorpion species had been identified. Krumpal & Cyprich (1988) tried to define ecological preferences of the 19 pseudoscorpion species found during their survey in the Czech Republic in 162 nests (representing 54 bird nest types) in relation to nest type (free nests, nests in nest boxes, nests in synanthropic habitats, nests in hollow trees) and seasonal changes. Ressl (1963) and Simon (1966), but also Jones (1978) discussed the eventual dispersal of pseudoscorpions by birds and the possible colonization of birds' nests. Recently, Christophoryova & Krumpalova (2010) distinguish within the pseudoscorpions nidixenous species (which occur accidentally in bird nests, the nymphal stages are represented sporadically) and nidiphilous or nidicolous species. They occur regularly in the bird nests, the nymphal stages are represented numerously, and prefer nests in certain habitats with specific building and microclimagtic conditions.

An ongoing study on nidicolous arthropods in birds' nests from Argentina (Turienzo & Di Iorio, 2008; Turienzo *et al.*, 2008, Di Iorio *et al.*, 2010; Turienzo & Di Iorio, unpublished data) has yielded 246643 insects, 5378 soft ticks (Acarina: Argasidae) and 6406 pseudoscorpions. Consequently, a summarization of the knowledge concerning the pseudoscorpions known from this biotope worldwide is needed for further comparison. The main purpose of the present work is to: 1) provide a compilation of the information on pseudoscorpion species and families recorded from birds' nests, and 2) state which bird species and families are involved worldwide.

## MATERIAL AND METHODS

The taxonomic and biological publications on pseudoscorpions were reviewed, as well as papers treating inhabitants of birds' nests; also included are unpublished identifications collated by one of us (V. M.). The bird families and species, followed by those of the associated pseudoscorpions, are listed in alphabetical order. All references were verified, except those indicated as "cited by", Museum collections and indications not given in original sources are cited between square brackets [ ]. Bird species lists of the American Ornithologists' Union (1998), Remsen *et al.* (2008) and the Comitê Brasileiro de Registros Ornitológicos (2007) were used for current nomenclature; subspecific taxa not treated in these lists were updated from Peterson (2002). The nomenclature of pseudoscorpions is adopted from Harvey (2009). Old combinations, synonyms, misidentifications, original localities, number of specimens, and depositories when they were stated, are provided in each case. Pertinent comments in the references and controversial data are included in notes below the respective items.

### Collections mentioned in the text

AM Australian Museum, Sydney, Australia.
BISHOP Bishop Museum, Honolulu, Hawaii.
CNCI Canadian National Collection of Insects, Ottawa, Canada.
EMB Ellen M. Benedict collection, Pacific University, Forest Grove, Oregon, USA

INPA Instituto Nacional de Pesquisas da Amazônia, Núcleo de Pesquisas em Ciências Humanas e Sociais, Manaus, Brazil.
LZPb Laboratorio de Zoología, Departamento de Biología, Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil.
MNRJ Museu Nacional, Rio de Janeiro, Brazil.
NHMW Naturhistorisches Museum, Wien, Austria.
WAM Western Australian Museum, Perth, Australia.

## PSEUDOSCORPION TAXA ASSOCIATED WITH BIRDS, NESTS AND GUANO

### ATEMNIDAE

*Anatemnus orites major* Beier: Pycnonotidae.
*Anatemnus orites orites* (Thorell): Apodidae.
*Diplotemnus insularis* Chamberlin: "in bird nests and on birds" (probably Sulidae and Laridae).
*Oratemnus navigator* (With): Apodidae.
*Paratemnoides nidificator* (Balzan): Passeriformes.

### CHEIRIDIIDAE

*Apocheiridium (A.) indicum* Murthy & Ananthakrishnan: Passeridae.
*Apocheiridium (A.) minutissimum* Beier: Accipitridae, Halcyonidae, Phasianidae.
*Apocheiridium (A.) rossicum* Redikorzev: Anatidae.
*Apocheiridium (A.) stannardi* Hoff: Anatidae.
*Cheiridium museorum* (Leach): Apodidae, Columbidae, Corvidae, Fringillidae, Hirundinidae, Motacillidae, Paridae, Passeridae, Phasianidae, Remizidae, Sturniidae, Turdidae; birds' nests.

### CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus): Apodidae, Columbidae, Corvidae, Fringillidae, Hirundinidae, Laridae, Phasianidae, Picidae, Strigidae, Sturniidae, Sylviidae, Turdidae, Tyrannidae; birds' nests.
*Chelifer cancroides orientalis* Morikawa: Hirundinidae.
*Chelifer* sp.: Passeridae.
*Dactylochelifer latreillei latreillei* (Leach): Columbidae, Emberizidae, Hirundinidae, Laniidae, Paridae, Passeriformes, Remizidae, Sylviidae, Turdidae.
*Hansenius torulosus* (Tullgren): Phasianidae.
*Paisochelifer callus* (Hoff): birds' nests.
*Rhacochelifer maculatus* (L. Koch): Phalacrocoracidae.

### CHERNETIDAE

*Acuminochernes crassipalpus* (Hoff): Strigidae.
*Acuminochernes tacitus* Hoff: Picidae.
*Allochernes powelli* (Kew): Hirundinidae, Passeriformes.
*Allochernes wideri* (C. L. Koch): Coraciidae, Corvidae, Muscicapidae, Paridae, Passeridae, Phasianidae, Picidae, Sittidae, Strigidae, Turdidae; birds' nests.
*Anthrenochernes stellae* Lohmander: Corvidae.
*Americhernes oblongus* (Say): Anatidae.
*Apatochernes antarcticus pterodromae* Beier: Procellariidae.

*Apatochernes nestoris* Beier: Procellariidae, Psittacidae.
*Calidiochernes musculi* Beier: Furnariidae, Troglodytidae.
*Chelanops skottsbergi* (Beier): Procellariidae.
*Chernes cimicoides* (Fabricius): Ardeidae, Hirundinidae, Laniidae, Paridae, Strigidae, Sylviidae.
*Chernes hahnii* (L. Koch): Meropidae, Paridae, Passeriformes; birds' nests.
*Chernes vicinus* (Beier): birds' nests.
*Chernes* sp.: Passeridae.
*Dendrochernes cyrneus* (L. Koch): Passeridae; birds' nests.
*Dinocheirus panzeri* (C. L. Koch): Columbidae, Corvidae, Hirundinidae, Laniidae, Paridae, Passeriformes, Phasianidae, Strigidae, Sturnidae, Sylviidae, Turdidae.
*Dinocheirus sicarius* Chamberlin: Phasianidae.
*Hesperochernes montanus* Chamberlin: Corvidae; birds' nests.
*Lamprochernes chyzeri* (Tömösvary): Phasianidae.
*Lamprochernes nodosus* (Schrank): Meropidae, Panuridae, Paridae, Remizidae; birds' nests.
*Lamprochernes savignyi* (Simon): Phasianidae; birds' nests.
*Lamprochernes* sp.: Hirundinidae.
*Neochelanops patagonicus* (Tullgren): birds' nests.
*Opsochernes carbophilus* Beier: birds' nests.
*Parachernes argentinus* Beier: Furnariidae; birds' nests.
*Parachernes* cf. *pulcher* Mahnert: Furnariidae.
*Parachernes squarrosus* Hoff: Turdidae.
*Parazaona bucheri* Beier: Furnariidae, Psittacidae.
*Parazaona morenensis* (Tullgren): Psittacidae.
*Pselaphochernes anachoreta* (Simon): Corvidae.
*Pselaphochernes scorpioides* (Hermann): Corvidae, Passeridae, Upupidae; birds' nests.
*Pselaphochernes lacertosus* (L. Koch): Procellariidae.
*Reischekia exigua exigua* Beier: Ardeidae.
*Rhopalochernes* sp.: Icteridae.
*Sundochernes malayanus* Beier: Pycnonotidae.
*Tejachernes stercoreus* (Turk): Hirundinidae.
*Troglochernes dewae* (Beier): Cacatuidae, Climacteridae.

CHTHONIIDAE

*Chthonius (Chthonius) ischnocheles* (Hermann): Hirundinidae, Turdidae.
*Chthonius (Chthonius) rhodochelatus* Hadzi: Passeridae.
*Chthonius (Ephippiochthonius) fuscimanus* Simon: Emberizidae, Passeriformes, Turdidae.
*Chthonius (Ephippiochthonius) tetrachelatus* (Preyssler): Anatidae, Passeriformes, Turdidae.
*Chthonius* sp.: Muscicapidae, birds' nests.
*Mundochthonius styriacus* Beier: Paridae.
*Pseudochthonius homodentatus* Chamberlin: Passeriformes, Turdidae.
*Tyrannochthonius heterodentatus* Beier: Passeridae.

*Tyrannochthonius kermadecensis* (Beier): Turdidae.
*Tyrannochthonius migrans* Mahnert: Troglodytidae.

GARYPIDAE
*Garypus titanius* Beier: in guano of birds' colonies.

GEOGARYPIDAE
*Geogarypus albus* Beier: Pycnonotidae; birds' nests.
*Geogarypus longidigitatus* (Rainbow): Cisticolidae, Estrilidae, Nectarinidae, Pycnonotidae.
*Geogarypus minor* (Tullgren): Cisticolidae.
*Geogarypus minutus* (Tullkgren): Cisticolidae.

IDEORONCIDAE
*Xorilbia* cf. *gracilis* (Mahnert): Troglodytidae.

LARCIDAE
*Larca lata* (Hansen): Phasianidae, Turdidae, Tytoniidae; birds' nests.
*Larca notha* Hoff: Hirundinidae.

NEOBISIIDAE
*Neobisium (Neobisium) carcinoides* (Hermann): Cinclidae, Emberizidae, Troglodytidae; birds' nests; birds' nests type *Motacilla*; nests Cinclidae+*Motacilla*.
*Neobisium (Neobisium) crassifemoratum* Beier: Tetraonidae; birds' nests.
*Neobisium (Neobisium) inaequale* Chamberlin: Sylviidae; birds' nests type *Motacilla*.
*Neobisium (Neobisium) sylvaticum* (C. L. Koch): Corvidae, Laniidae, Sylviidae, Turdidae.
*Neobisium* sp.: Emberizidae, Hirundinidae, Motacillidae, Turdidae.

OLPIIDAE
*Calocheiridius olivieri* (Simon): Phalacrocoracidae.
*Indolpium loyolae* (Murthy): Passeridae.
*Pachyolpium irmgardae* Mahnert: Formicariidae, Troglodytidae.
*Xenolpium pacificum pacificum* (With): birds' nests.

PSEUDOGARYPINIDAE
*Pseudogarypinus frontalis* (Banks): birds' nests.

SYARINIDAE
*Ideobisium* sp.: Passeriformes.

WITHIIDAE
*Dolichowithius argentinus* Beier: birds' nests.
*Stenowithius bayoni* (Ellingsen): Anatidae, Laniidae.
*Stenowithius duffeyi* Beier: birds' guano in nesting colonies.
*Victorwithius proximus* (Beier): Furnariidae.
*Withius indicus* Murthy & Ananthakrishnan: Phasianidae.
*Withius kaestneri* (Vachon): Phasianidae.
*Withius piger* (Simon): Phasianidae.

## BIRD TAXA AND ASSOCIATED PSEUDOSCORPIONS

### ACCIPITRIDAE

***Ictinaetus malayensis*** Temminck, 1892

CHEIRIDIIDAE

*Apocheiridium minutissimum* Beier, 1964

Malaysia: Pahang, Fraser's Hill, 15-I-1956, McClure leg., 1 exuvia, Ser. No. M-03118, Band No. H. 87082, in a nest of Black Eagle (Beier, 1964).

### ANATIDAE

***Aix sponsa*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Apocheiridium stannardi* Hoff, 1952

USA: Michigan, Shiawassee County, in nest box (Nelson, 1971: "accidental occurrence?").

CHERNETIDAE

*Americhernes oblongus* (Say, 1821) (= *Lamprochernes oblongus*: Nelson, 1971).

USA: Michigan, Shiawassee County, in nest box (Nelson, 1971: "accidental occurrence").

***Anas platyrhynchos*** (Linnaeus, 1758)

CHTHONIIDAE

*Chthonius (Ephippiochthonius) tetrachelatus* (Preyssler, 1790)

Slovakia: (Fenda *et al*., 1998).

***Anas undulata*** (Dubois, 1839)

WITHIIDAE

*Stenowithius bayoni* (Ellingsen, 1910)

Uganda: Chagwe, Seziwa Swamps (Ellingsen, 1913; Beier, 1948).

**Undetermined species** ("wild duck": Redikorzev, 1938; Beier, 1948).

CHEIRIDIIDAE

*Apocheiridium rossicum* Redikorzev, 1935

Russia: Siberia, Ienissei, on head of wild duck (Redikorzev, 1938; Beier, 1948).

### APODIDAE

***Apus affinis*** (Gray, 1830) (= *Cypselus affinis*: Ellingsen, 1914, Beier, 1948).

ATEMNIDAE

*Anatemnus orites orites* (Thorell, 1889)

India: Calcutta, from a nest in the Museum buildings (Ellingsen, 1914; Beier, 1948).

*Oratemnus navigator* (With, 1906)

India: Calcutta, from a nest in the Museum buildings (Ellingsen, 1914; Beier, 1948).

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

India: Calcutta, from a nest in the Museum buildings (Ellingsen, 1914; Beier, 1948).

***Apus apus*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Scheibbs Distr. (Ressl & Beier, 1958; Ressl, 1963, 1983).

ARDEIDAE

***Ardea cinerea*** Linnaeus, 1758

CHERNETIDAE

*Chernes cimicoides* (Fabricius, 1793)

England: Kent, High Halstow (Jones, 1975, 1978).

***Egretta alba modesta*** (Gray, 1831)

CHERNETIDAE

*Reischekia exigua exigua* Beier, 1976

New Zealand: Westland, Okarito, in old broken-down white heron nests, sample 68/5 (Beier, 1976).

CACATUIDAE

***Cacatua galerita galerita*** (Latham, 1790)

CHERNETIDAE

*Troglochernes dewae* (Beier, 1967)

Australia: Queensland, Fringe Dwellers, Iron Range, *circa* 12°38'S, 143°05'E, 9-X-1998, S. Legge & R. Heinsohn leg., 1♂ [WAM T66299], nest of Sulphur-Crested Cockatoo (Harvey & Volschenk, 2007).

***Calyptorhynchus latirostris*** Carnaby, 1948 (= *Cacatua latirostris*: Harvey & Volschenk, 2007).

CHERNETIDAE

*Troglochernes dewae* (Beier, 1967)

Australia: Western Australia, Shire of Moora, 30°35'S, 116°01'E, 20-XI-1998, P. Mawson leg., 1♂ [WAM T66300], ex nest in healthy hollow of *Eucalyptus salmonophloia* (Harvey & Volschenk, 2007); Gingin Shire, 30°59'S, 115°45'E, 20-XI-1998, P. Mawson leg., 1 tritonymph, 1♀ [WAM T48341], ex nest # 84 (Harvey & Volschenk, 2007).

***Eulophus roseicapilla*** (Vieillot, 1817) (= *Cacatua roseicapilla*: Beier, 1967; Harvey & Volschenk, 2007).

CHERNETIDAE

*Troglochernes dewae* (Beier, 1967) (= *Sundochernes dewae*: Beier, 1967).

Australia: New South Wales, Brewarrina, 29º58'S, 146º52'E, ♂ holotype [AM KS5867], 1 protonymph, 2 deutonymphs, 2 tritonymphs, 1♀ (paratypes) [AM KS5868], 1 nymph, 1♂, 2♀ (paratypes) [NHMW], V-1964, B. Dew leg., from nest of Galah in hollow tree (Beier, 1967, Harvey & Volschenk, 2007).

CINCLIDAE

***Cinclus cinclus*** (Linnaeus, 1758)

NEOBISIIDAE

*Neobisium (Neobisium) carcinoides* (Hermann, 1804)

Slovakia: (Fenda *et al.*, 1998).

***Cinclus cinclus*** (Linnaeus, 1758) + ***Motacilla*** sp.

*Neobsium (Neobisium) carcinoides* (Hermann, 1804)

Slovakia: (Fenda *et al.*, 1998).

CISTICOLIDAE

***Cisticola lais*** Hartlaub & Finsch, 1870

GEOGARYPIDAE

*Geogarypus minutus* (Tullgren, 1907) (= *Garypus minutus*: Elingsen, 1912).

South Africa: Cape Province, King William's Town Div.: Pirie, a very immature specimen rather doubtfully referable to *G. minutus*, from a nest of a grass warbler (*Cisticola lais* Sharpe) (Ellingsen, 1912).

***Prinia flaviventris*** (Delessert, 1840)

GEOGARYPIDAE

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963a).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 12-VII-1961, 1 tritonymph, nest 234, B.53395 (Beier, 1963a).

CLIMACTERIDAE

***Climacteris rufa*** Gould, 1841

CHERNETIDAE

*Troglochernes dewae* (Beier, 1967)

Australia: Western Australia, Yilliminning Agricultural Region, 32º56'S, 117º25'E, 6-III-1999, G. Luck leg., 1 deutonymph, 2 tritonymphs, 1♂, 1♀ [WAM T66301], ex nest # 206 (Harvey & Volschenk, 2007).

COLUMBIDAE

***Columba livia domestica*** Gmelin, 1789 (= *Columba* sp., city pigeon: Woodroffe, 1953).

CHEIRIDIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963).

England: Leicester, The Newarke, from nest of feral pigeon (Jones, 1975).
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).
Germany: Rheinland-Westfalen, Peppenhoven am Vorgebirge; Morenhoven am Vorgebirge, in einem Taubenschlag (Ellingsen, 1911; Beier, 1948).

[Undetermined species]

Brazil: Amazonas, Manaus, VII/XI-2005, 3 ex. [INPA] in nest # 5, 4 ex. [INPA] in nest # 8 from a total of 14 examined nests, 0.28% of total arthropods (Ogawa, 2008).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).
England: abundant in some pigeons' nests (Woodroffe, 1953).
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).
Germany: Rheinland-Westfalen, Peppenhoven am Vorgebirge, in einem Taubenschlag (Ellingsen, 1911; Beier, 1948).
Sweden: (Lohmander, 1939; Beier, 1948).

CHERNETIDAE

*Dinocheirus panzeri* (C. L. Koch, 1837)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
Ireland: Portaferry, County Down, pigeon's nest in an old tower (Legg & O'Connor, 1997; Jones, 1975).

***Columba oenas*** Linnaeus, 1758

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

*Dactylochelifer latreillei* (Leach, 1817)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936; Krištofik *et al.*, 1993, 2002) (mis-identified, see *Chernes cimicoides*).

CHERNETIDAE

*Chernes cimicoides* (Fabricius, 1793) and *Dinocheirus panzeri* (C. L. Koch, 1837)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936). The samples detemined as *D. latreillei* consist of individuals of two other species, *Chernes cimicoides* and *Toxochernes (= Dinocheirus) panzeri* (Kaisila, 1949).

CORACIIDAE

***Coracias garrulus*** Linnaeus, 1758

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Slovakia (and/or Austria-Czech Republic) (Christophoryova & Krumpalova, 2010).

CORVIDAE

***Corvus corone corone*** Linnaeus, 1758

CHERNETIDAE

*Chernes hahnii* L. Koch, 1873

France: Haute-Savoie, Bossy-sur-Frangy, nid, 6-V-1972, leg. J. Steffen, 1♂, det.V. Mahnert.

*Pselaphochernes anachoreta* (Simon, 1878)

France: Haute-Savoie, Bossy-sur-Frangy, nid, 6-V-1972, leg. J. Steffen, 1♀, det.V. Mahnert.

NEOBISIIDAE

*Neobisium (Neobisium) sylvaticum* (C. L. Koch, 1835)

Austria: Lower Austria, Scheibbs Distr. (Ressl & Beier, 1958; Ressl 1983).

*Note*: Records of *Chelifer cancroides*, *Allochernes wideri* and *Dinocheirus panzeri* from nests of *Corvus corone* by Ressl (1963) were apparently due to a typographical error, and concern the occurrence in nests of *Sturnus vulgaris*. They were implicitly corrected by Ressl (1983).

***Corvus monedula*** Linnaeus, 1758 (= *Colaeus monedula*: Nordberg 1936).

CHEIRIDIIDAE

*Cheiridium museorum* (Lach, 1817)

United Kingdom: Wales, Ceredigion, in a jackdaw's nest in the lofts (Chater, 1989).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Germany: Hessen, Wiesbaden, Biebricher Schlosspark, nest in broken *Populus alba* (Helversen, 1966).

*Anthrenochernes stellae* Lohmander, 1939

Sweden: Blekinge, probably nest of *C. monedula* (Gärdenfors & Wilander, 1995).

*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Toxochernes panzeri* (C. L. Koch); = *Chernes rufeolus* (Simon): Helversen, 1966).

Germany: Hessen, Wiesbaden, Biebricher Schlosspark, nest in broken *Populus alba* (Helversen, 1966).

Sweden: Skane, Torna Hällestad; Östergötland, Alvastra (Lohmander, 1939; Beier, 1948); probably nest of *C. monedula* (Gärdenfors & Wilander, 1995).

*Pselaphochernes scorpioides* (Hermann, 1804)

England: Berkshire, Wytham Wood, Jackdaw's nest at 15 ft in an oak tree (Jones, 1975, 1978).

***Pica hudsonia*** Sabine, 1823 (= *Pica pica hudsonicus* Sabine: Chamberlin, 1935).

CHERNETIDAE

*Hesperochernes montanus* Chamberlin, 1935

USA: Montana, Bitterroot Valley, 1931, "one pseudoscorpion that has been determined as *Hesperochernes montanus* new species by J. C. Chamberlin who is describing this arachnid elsewhere" (Jellison & Philip, 1933), Ravally County, Girds Creek, 30-V-1931, W. L. Jellison leg., 1♂, # JC-796.01001, in a bird's nest (Chamberlin, 1935; Beier, 1948).

EMBERIZIDAE

***Emberiza citrinella*** Linnaeus, 1758

CHTHONIIDAE

*Chthonius (Ephippiochthonius) fuscimanus* Simon, 1900 (= *Chthonius austriacus*: Ressl, 1963).

Austria: Lower Austria, Scheibbs Distr., Purgstall (Ressl, 1963, 1983).

CHELIFERIDAE

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl & Beier, 1958; Ressl, 1963, 1983).

NEOBISIIDAE

*Neobisium (Neobisium) carcinoides* (Hermann, 1804)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Neobisium* sp.

Slovakia: (Fenda *et al*., 1998).

ESTRILDIDAE

***Lonchura maja*** (Linnaeus, 1766)

GEOGARYPIDAE

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963a).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 15-III-1961, 1 tritonymph, nest 54, B.53085 (Beier, 1963a).

***Lonchura malacca*** (Sykes, 1832)

GEOGARYPIDAE

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963a).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 18-I-1961, 1 D, 1 T, 3♂, 1♀, nest 13, B.52897; 31-V-1961, 1♀, nest 166, B.53259; 14-VI-1961, 2♂, nest 192, B.53341 (Beier, 1963a).

***Lonchura punctulata*** (Linnaeus, 1758)

GEOGARYPIDAE

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963a).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 18-X-1961, 1 gravid ♀, nest 250, B.53576 (Beier, 1963a).

FORMICARIIDAE

**Formicariidae** sp. 2

Olpiidae

*Pachyolpium irmgardae* Mahnert, 1979

Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40' W, VII/XII-2000, 1 nymph (Torres, 2001).

FRINGILLIDAE

***Fringilla coelebs*** Linnaeus, 1758

Cheiridiidae

*Cheiridium museorum* (Leach, 1817)

Europe: (Roewer, 1937; Beier, 1948).

Cheliferidae

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Finland: Arland (? Tvärminne or Helsingfors) (Nordberg, 1936; Kaisila, 1949).

FURNARIIDAE

***Anumbius annumbi*** (Vieillot, 1817)

Chernetidae

*Parachernes* cf. *pulcher* Mahnert, 1979

Argentina: Córdoba, Dto Unión, Bell Ville (Grimaldi *et al.*, 2006).

*Parazaona bucheri* Beier, 1967

Argentina: Santa Fe, near Santa Fe City, in a nest superimposed to a nest of *Phacellodomus ruber* (Vieillot, 1817) [Aves: Furnariidae] (Turienzo *et al.*, 2008).

Withiidae

*Victorwithius proximus* (Ellingsen, 1905)

Argentina: Buenos Aires [Campo de Mayo] (Turienzo *et al.*, 2008).

***Phacellodomus ruber*** (Vieillot, 1817)

Chernetidae

*Parazaona bucheri* Beier, 1967

Argentina: Santa Fe, near Santa Fe City (Turienzo *et al.*, 2008).

***Phacellodomus rufifrons inornatus*** Ridgway, 1887

Chernetidae

*Calidiochernes musculi* Beier, 1957

Venezuela: "Alta Gracia de Oviteno", det. M. Beier, in nest, hand-written note by M. Beier in his private copy of Beier, 1957a: 138.

Monosphyronida

undetermined species

Colombia: Department of Meta, El Porvenir, 4°45'N, 71°25'W, in 22 examined nests (Barreto *et al.*, 1984).

UNDETERMINED FAMILY

Undetermined species (= "*Chelifer* sp.": Pifano, 1938).

Venezuela: Estado Yaracuy, Distrito San Felipe, Carretera San Javier - Marín, II-1938, Anduze & Pifano leg., in company of Coleoptera and *Psammolestes arthuri* (Pinto) [Hemiptera: Reduviidae] (Pifano, 1938; Carcavallo *et al.*, 1975).

***Phacellodomus rufifrons rufifrons*** (Wied-Neuwied, 1821)

PSEUDOSCORPIONES, undetermined species

Brazil: Goias (Silva & Lustosa, 1993).

***Phacellodomus rufifrons sincipitalis*** Cabanis, 1883

PSEUDOSCORPIONES, undetermined species

Brazil: (Lent, 1939); Pernambuco, March to June 1970, 344 ex. [LZPb], from a total of 28 nests (Lins Duarte, 1978).

***Phacellodomus*** sp.

CHERNETIDAE

*Parachernes argentinus* Beier, 1967

Argentina: Tucumán, La Soledad, near Cañete, 1965-1966, identified by Beier (Bucher, 1974).

*Parazaona bucheri* Beier, 1967

Argentina: Tucumán, Tapia-Raco, identified by Beier (Bucher, 1974).

*Note*: *P. argentinus* and *P. bucheri* were described by Beier (1967) on specimens collected by Bucher in 1966 and sent to Beier for identification. Bucher (1974) specified that the specimens had been collected from nests of *Phacellodomus*, information probably unknown to Max Beier.

HALCYONIDAE

***Halcyon pileata*** (Boddaert, 1783)

CHEIRIDIIDAE

*Apocheiridium minutissimum* Beier, 1964

Malaysia: Subang, 12-XII-1962, H. E. McClure leg., ♀ holotype [BISHOP 3603], Ser. No. M-02066, Band No. H. 87082, in nest (Beier, 1964).

HIRUNDINIDAE

***Delichon urbica*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr., Purgstall (Ressl, 1963, 1983).

Scotland: near Rannoch, Perthshire, in nest of house martin (Jones, 1975, 1978).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, 1862, Ferrari leg, "aus einem Schwalbennest" (Beier, 1929a); under *Hirundo rustica* and *Delichon urbica* (Beier, 1948); Scheibbs Distr. (Ressl, 1963 1983).

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

Sweden: Östergötland, Lake Täkern, leg. V. A. Engholm (Lohmander, 1939; Beier, 1948).

Switzerland: (Lessert, 1911; Beier, 1948); canton of Vaud, Commugny, 1964/1966, in nests, leg. J. Steffen, 5♂, 10♀, 1 trito-, 3 deutonymphs, det. V. Mahnert.

*Chelifer cancroides orientalis* Morikawa, 1954

Japan: Nagano Prefecture, Agematsu Town, 17-XI-1967, in 8 examined nests (Uchikawa, 1970).

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936; Krištofik *et al.*, 1993) (mis-identified, see *Chernes cimicoides*).

CHERNETIDAE

*Chernes cimicoides* (Fabricius, 1793) and *Dinocheirus panzeri* (C. L. Koch, 1837)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936). The samples detemined as *D. latreillei* consist of individuals of two other species, *Chernes cimicoides* and *Toxochernes (=Dinocheirus) panzeri* (Kaisila, 1949).

CHTHONIIDAE

*Chthonius (Chthonius) ischnocheles* (Hermann, 1804)

England: Churcham, Gloucestershire (Jones, 1975).

***Delichon urbica*** (Linnaeus, 1758) + *Passer domesticus* (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

England: Ashleworth, Gloucestershire, in nest of house martin, later occupied by sparrow (Jones, 1975, 1978).

***Hirundo rustica*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Europe (?): (Roewer, 1937; Beier, 1948).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Dornbach bei Wien, 1862, Ferrari leg., "aus einem Schwalbennest" (Beier, 1929a); "*Hirundo rustica*" (Beier, 1948); Scheibbs Distr. (Ressl & Beier, 1958; Ressl 1963, 1983).

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

France: Haute-Savoie, Bossy-sur-Frangy, 450m, in nests in stable and kitchen of farmstead, 1969-1980, leg. J. Steffen, det. V. Mahnert.

Germany: Hessen, Naturpark Hoher Vogelsberg, Ilbeshausen (Jost, 1982).

Sweden: (Lohmander, 1939).

Switzerland: (Lessert, 1911; Beier, 1948); canton of Vaud, Commugny, in nest, 8-VII-1962, leg. J. Steffen, 3♂, 1♀, det. Mahnert.

USA: Oregon, Lane Co., 2.5 mi N of Cheshire, 4-XII-1971, leg. E. M. Benedict, 5 nymphs, 5♂, 4♀ [EMB], hay, mouse and barn swallow nests in old sheep shed (Benedict & Malcolm, 1979).

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936; Krištofik *et al.*, 1993, 2002) (mis-identified, see *Chernes cimicoides*).

CHERNETIDAE

*Allochernes powelli* (Kew, 1916)

Germany: Hessen, Naturpark Hoher Vogelsberg, Ilbeshausen (Jost, 1982).

*Chernes cimicoides* (Fabricius, 1793) and *Dinocheirus panzeri* (C. L. Koch, 1837).

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg 1936). Samples identified by Nordberg as *D. latreillei* consist of individuals of two other species, *Chernes cimicoides* and *Toxochernes (=Dinocheirus) panzeri* (Kaisila, 1949).

*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Toxochernes panzeri* (C. L. Koch, 1837).

Austria: Dornbach bei Wien, in einem Schwalbennest (Beier, 1929a); nest of *Hirundo rustica* (Beier, 1948).

***Progne subis*** (Linnaeus, 1758) + *Passer domesticus* (Linnaeus, 1758)

CHELIFERIDAE

*Chelifer* sp.

USA: Wisconsin, near Madison, 26-X-1962, 15 adults in a Purple Martin house occupied by House Sparrows (Thompson, 1966).

***Riparia riparia*** Linnaeus, 1758 (= bank swallows: Muchmore, 1981).

CHERNETIDAE

*Lamprochernes* sp.

Slovakia: Chotín, 5 February 1990, 1 deutonymph (Krištofik *et al.*, 1994).

LARCIDAE

*Larca notha* Hoff, 1961

Canada: Saskatchewan, Val Marie, 10-VI-1955, J. R. Vockeroth leg., 1 deutonymph, 3 tritonymphs, 3♂, 2♀ [CNCI], from the nest (Muchmore, 1981).

NEOBISIIDAE

*Neobisium* sp.

Slovakia: (Fenda *et al.*, 1998).

**Undetermined sp.** (= "swallow's nest": Hoff, 1957).

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

United Kingdom: Wales, Ceredigion, in two swallow nests (Chater, 1989).

CHERNETIDAE

*Tejachernes stercoreus* (Turk, 1949)

USA: Texas, Uvalde County, Frio Cave, from swallow nest constructed from mud at cave entrance (Hoff, 1957).

ICTERIDAE

***Psarocolius decumanus*** (Pallas, 1769)

CHERNETIDAE

*Rhopalochernes* sp.

Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 4 nymphs, 9 adults in nest # 59, 21 nymphs, 21 adults in nest # 60, 84 nymphs, 19 adults in nest # 61, 17 nymphs, 23 adults in nest # 62, 13 nymphs, 18 adults in nest # 63, 35 nymphs, 13 adults in nest # 64, 7 nymphs, 5 adults in nest # 65 of a total of 7 examined nests [Colony 2] (Torres, 2001).

LANIIDAE

***Lanius collaris*** Linnaeus, 1766

WITHIIDAE

*Stenowithius bayoni* (Ellingsen, 1910)

South Africa: Cape Province, King William's Town Div., Pirie, in the nest of the Fiscal Shrike (Ellingsen, 1912; Beier, 1948).

***Lanius collurio collurio*** Linnaeus, 1758

CHELIFERIDAE

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Slovakia: Vysoká pri Morave, 2-VIII-1993, 1♂; Lehnice, 15-VII-1993, 1♀; Gabčíkovo, 19-VII-1994, 1 tritonymph, 3♂, 1♀; Ipelské Predmostie, 21-VII-1994, 1♂, 1♀ (Krištofik *et al.*, 2002).

NEOBISIIDAE

*Neobisium (Neobisium) sylvaticum* (C. L. Koch, 1835)

Slovakia: Očová, 6-VII-1993, 1 tritonymph, 1♀ (Krištofik *et al.*, 2002).

***Lanius minor minor*** Gmelin, 1788

CHERNETIDAE

*Chernes cimicoides* (Fabricius, 1793)

Slovakia: Detva, settlement of Latok, 19-VII-1996, 1♀ (Krištofik *et al.*, 2002).

*Dinocheirus panzeri* (C. L. Koch, 1837)

Slovakia: Holice, 5-VII-1994, 3 tritonymphs, 1♂, 2♀ (Krištofik *et al.*, 2002).

LARIDAE

***Larus delawarensis*** Ord, 1815

PSEUDOSCORPIONES, undetermined species

Canada: Lake Superior, Black Bay, Granite Island, 48°43'N, 88°29'W, 9-V-1983 through 29-VI-1983, 5 specimens out of a total of 40 collected gull nests (Ryder & Freitag, 1974).

***Larus ridibundus*** Linnaeus, 1766

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Sweden: Lake Takern, Östergötland (Lohmander, 1939; Beier, 1948).

MEROPIDAE

***Merops apiaster*** Linnaeus, 1758

CHERNETIDAE

*Chernes hahnii* (C. L. Koch, 1839)

Slovakia: Chotín, 48°11'N, 18°14'E, 22-VIII-1991, 1♂ in one of 9 examined nests (Krištofik *et al.*, 1996).

*Lamprochernes nodosus* (Schrank, 1761)

Slovakia: Jarovce, 47°14'N, 17°06'W, 16-VIII-1993, 1♀ in one of 21 examined nests (Krištofik *et al.*, 1996).

MOTACILLIDAE

***Anthus trivialis*** (Linnaeus, 1758)

NEOBISIIDAE

*Neobisium* sp.

Slovakia: (Fenda *et al.*, 1998).

***Motacilla alba*** Linnaeus, 1758

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

MUSCICAPIDAE

***Ficedula albicollis*** (Temminck, 1815)

CHTHONIIDAE

*Chthonius* sp.

Slovakia: (Fenda *et al.*, 1998).

NEOBISIIDAE

*Neobisium* sp.

Slovakia: (Fenda *et al.*, 1998).

PSEUDOSCORPIONES

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

***Ficedula hypoleuca*** (Pallas, 1764)

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Finland: Korppoo (V), in a nesting box, where *Muscicapa hypoleuca* had been nesting previously, but where bats were living when the nest was investigated (Kaisila, 1949).

NECTARINIIDAE
***Anthreptes malacensis*** (Scopoli, 1786)
GEOGARYPIDAE
*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963a).
Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 7-VI-1961, 1 deutonymph, in nest 178 (Beier, 1963a).

PANURIDAE
***Panurus biarmicus*** (Linnaeus, 1758)
CHERNETIDAE
*Lamprochernes nodosus* (Schrank, 1803)
Italy: Po River delta, Argenta, 44°41'N, 11°50'E, 1♂, 1♀; Campotto, 44°42'N, 11°50'E, 1♀ (Krištofik *et al*., 2007).

PARIDAE
***Parus caeruleus*** (Linnaeus, 1758)
CHERNETIDAE
*Allochernes wideri* (C. L. Koch, 1843)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).
*Chernes hahnii* (C. L. Koch, 1839)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

***Parus major*** Linnaeus, 1758
CHERNETIDAE
*Allochernes wideri* (C. L. Koch, 1843)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
*Dinocheirus panzeri* (C. L. Koch, 1837)
England: Churchdown, Gloucestershire (George, 1961; Jones, 1975, 1978).

CHTHONIIDAE
*Mundochthonius styriacus* Beier, 1971
Austria: Styria, Pöls bei Zwaring, 20 km S of Graz, in nest 3.5 m above ground (Beier, 1971; Jost, 1982).

***Parus montanus*** (Conrad von Baldenstein, 1827)
CHELIFERIDAE
*Dactylochelifer latreillei latreillei* (Leach, 1817)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936; Krištofik *et al*., 1993) (mis-identified, see *Chernes cimicoides*).

CHERNETIDAE
*Chernes cimicoides* (Fabricius, 1793) and *Dinocheirus panzeri* (C. L. Koch, 1837)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936). Samples identified by Nordberg as *D. latreillei* consist of individuals of two other species, *Chernes cimicoides* and *Toxochernes (= Dinocheirus) panzeri* (Kaisila, 1949).

PASSERIDAE

***Passer domesticus*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Apocheiridium indicum* Murthy & Ananthakrishnan, 1977

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, b, 1999).

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

England: Kirton-in-Kindsey, Lincolnshire, in deserted sparrow nest (Pickard-Cambridge, 1892); Churchdown, Gloucestershire; Woodwalton Fen N.N.R., Hunts. (Jones, 1975, 1978).

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, 1999).

Switzerland: (Lessert, 1911; Beier, 1948).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

France: Haute-Savoie, Bossy-sur-Frangy, 450m, nest in farm stable, VI-1969, leg. J. Steffen, 2♂, 7♀, 6 tritonymphs, 1 deutonymph, det. V. Mahnert.

Sweden: (Lohmander, 1939; Beier, 1948).

Switzerland: (Lessert, 1911; Beier, 1948); Geneva City, Natural History Museum, 2♂, 2♀, 1983/1993, from nests, det. V. Mahnert.

*Chelifer* sp.

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, 1999).

CHERNETIDAE

*Chernes* sp.

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, 1999).

*Pselaphochernes scorpioides* (Hrmann, 1804)

Germany: "Ostdeutschland", in nest of house sparrow (Drogla & Lippold, 2004).

CHTHONIIDAE

*Chthonius (Chthonius) rhodochelatus* Hadzi, 1933

France: Haute-Savoie, Bossy-sur-Frangy, 450 m, in nest fallen from a tree, 22-X-1972, leg. J. Steffen, 1♀, det. V. Mahnert.

*Tyrannochthonius heterodentatus* Beier, 1930 (= *Tyrannochthonius madrasensis* Murthy, 1961: Bhattacharyya, 1990a, 1999).

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, 1999).

OLPIIDAE

*Indolpium loyolae* (Murthy, 1961) (= *Minniza loyolae*: Bhattacharyya, 1990a, 1999).

India: West Bengal, 1984-1985, from a total of 192 nests (Bhattacharyya, 1990a, 1999).

***Passer montanus*** (Linnaeus, 1758)

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

*Dendrochernes cyrneus* (L. Koch, 1873)

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krunmpalova, 2010).

***Prunella modularis*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Tirol, Ötztaler Alpen, Obergurgl, 2000 m (Thaler, 1979).

PASSERIFORMES, undetermined genera and species

ATEMNIDAE

*Paratemnoides nidificator* (Balzan, 1888) (= *Paratemnoides minor* (Balzan): Torres, 2001)

Brazil: Amazonas: Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 1 nymph in nest # 4 (Torres, 2001).

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Allochernes powelli* (Kew, 1916)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Dinocheirus panzeri* (C. L. Koch, 1837)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Chernes hahnii* (C. L. Koch, 1839)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

CHELIFERIDAE

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

CHTHONIIDAE

*Chthonius (Ephippiochthonius) tetrachelatus* (Preyssler, 1790)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Chthonius (Ephippochthonius) fuscimanus* Simon, 1900 (= *Chthonius (E.) austriacus*: Ressl, 1983).

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

*Pseudochthonius homodentatus* Chamberlin, 1929

Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 1♀ in nest # 20 (Torres, 2001).

SYARINIDAE

*Ideobisium* sp.

Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 1 nymph, 1♂ in nest # 20 (Torres, 2001).

## PHALACROCORACIDAE

***Phalacrocorax aristotelis*** (Linnaeus, 1761)

CHELIFERIDAE

*Rhacochelifer maculatus* (L. Koch, 1873)

France: Corsica, Îles Lavezzi, Rattino, VI.1983, leg. C. Guiguen, 2♀, det. V. Mahnert.

OLPIIDAE

*Calocheiridius olivieri* (Simon, 1879)

France: Corsica, Îles Lavezzi, Rattino, VI.1983, leg. C. Guiguen, 2♂, 2♀, det. V. Mahnert.

## PHASIANIDAE

***Gallus gallus*** (Linnaeus, 1758) (= *Gallus domesticus*: Ressl, 1963).

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

United Kingdom: Wales, Ceredigion, in hen's nests of straw in an outbuilding (Chater, 1989).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

USA: Illinois (Hoff 1944); Colorado: Weld County, 2♂, east of Latham Reservoir, SE of Greeley, in chicken house (Hoff, 1961).

*Hansenius torulosus* (Tullgren, 1907) (= *Chelifer kewi*: Ellingsen 1912).

South Africa: Cape Province: in a hen-house (Ellingsen, 1912).

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

*Dinocheirus panzeri* (C. L. Koch, 1837)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963; 1983).

*Dinocheirus sicarius* Chamberlin, 1952

USA: Oregon, Lane Co., 5 mi N of Elmira (130 m), litter-dung of chicken house (Benedict & Malcolm, 1982).

*Lamprochernes chyzeri* (Tömösvary, 1882)
Switzerland: canton of Geneva, Avully, in chicken dung, 6-IX-1966, leg. Cl. Besuchet, 1♀, 1 trito-, 1 deutonymph, det. V. Mahnert.
*Lamprochernes savignyi* (Simon, 1881)
New Zealand: chicken coops (Beier, 1976).
South Africa: Medunsa, 30 km NW Pretoria, VI.1999, leg. Green, 1♂, 1♀, in chicken litter, det. V. Mahnert.
LARCIDAE
*Larca lata* (Hansen, 1884)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

WITHIIDAE
*Withius indicus* Murthy & Ananthakrishnan, 1977
India: Tamil Nadu, in chicken house (Murthy & Ananthakrishnan, 1977).
*Withius kaestneri* (Vachon, 1937)
South Africa: Cape Province, Albany Distr., 33°32'S, 26°34'W, 10.V.1979 D. Gautier leg., 12♂, 6♀, in chicken dung, det. V. Mahnert (published by Hulley, 1983); in manure samples from poultry farms in Albany Distr. (33°32'S, 26°34'E), Bathurst Distr. (33°34'S, 26°43'S), Ciskei (33°24'E, 27°08'E), East London (32°53'S, 27°53'E), and Port Elizabeth (33°54'S, 25°09'E) (Hulley, 1983).
*Withius piger* (Simon, 1878) (= *Withius subruber*: Beier, 1976; = *Whitius piger*: Pinto *et al*., 2005).
Brazil: Rio Grande do Sul: Pelotas, in poultry farm (Pinto *et al*., 2005).
New Zealand: Auckland, Kumeu, in chicken manure, sample # 75/144 (Beier, 1976).

PSEUDOSCORPIONES
USA: California, Sonomo County, in poultry manure (Peck & Anderson, 1969); California, Riverside County, in caged layer poultry manure (Wills *et al*., 1990); Florida, Putnam Co., in poultry manure (Propp & Morgan, 1985).

***Polyprectrom inopinatum*** (Rothschild, 1903)
CHEIRIDIIDAE
*Apocheiridium minutissimum* Beier, 1964
Malaysia: Pahang, Fraser's Hill, 26-III-1957, 1♂ (torso) paratype, Ser. No. M-02117, Band No. H. 87082, in nest of Rothchild's Peacock Pheasant (Beier, 1964).

PICIDAE
***Colaptes auratus cafer*** (Gmelin, 1788) (= *Colaptes cafer*: Hoff, 1961).
CHERNETIDAE
*Acuminochernes tacitus* Hoff, 1961
USA: Colorado, Larimer County, 2.5 miles east of Fort Collins, at about 5000 feet in elevation (Hoff, 1961).

***Dendrocopus medius*** (Linnaeus, 1758)
CHERNETIDAE
*Allochernes wideri* (C. L. Koch, 1843)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

***Dryocopus martius*** (Linnaeus, 1758)
CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

***Picoides borealis*** Vieillot, 1809
PSEUDOSCORPIONES, unidentified species
USA: Georgia, Fort Stewart Military Reservation, 1997-1998, 7% of all cavities or 15% of natural cavities of a total of 42 examined cavities [20 natural cavities, 22 insert cavities] (Pung *et al.*, 2000).

PROCELLARIIDAE
***Calonectris diomedea*** (Scopoli, 1796)
CHERNETIDAE
*Pselaphochernes lacertosus* (L. Koch, 1873)
Portugal: Islas Selvagem, Selvagem Grande, 1984, P. D. Gabbutt leg., 7♂, 7♀ 5 tritonymphs, in nests, det. V. Mahnert.

***Pachyptila turtur*** Kuhl, 1820
CHERNETIDAE
*Apatochernes antarcticus pterodromae* Beier, 1964
New Zealand: Auckland Is. (Ocean I.), Stewart I. (Motunau I.) (Beier, 1976).

***Procellaria westlandica*** (Falla, 1946)
CHERNETIDAE
*Apatochernes nestoris* Beier, 1962
New Zealand: North I., Bay of Plenty (Whale I.); South I., Westland (Nelson Creek, Barrytown, Murrays Mistake; Open Bay Is.); Stewart I. (Bench I.) (Beier, 1976).

***Pterodroma externa externa*** (Salvin, 1875)
CHERNETIDAE
*Chelanops skottsbergi* (Beier, 1957) (= *Stigmachernes skottsbergi*: Beier, 1957b).
Chile: Juan Fernandez Is., Masafuera, probably in phagophily within the birds' colonies (Beier, 1957b).

***Pterodroma macroptera*** (A. Smith, 1840)
CHERNETIDAE
*Apatochernes nestoris* Beier, 1962
New Zealand: North I., Bay of Plenty (Whale I.); South I., Westland (Nelson Creek, Barrytown, Murrays Mistake; Open Bay Is.); Stewart I. (Bench I.) (Beier, 1976).

***Pterodroma lessoni*** (Garnot, 1826)

CHERNETIDAE

*Apatochernes antarcticus pterodromae* Beier, 1964

New Zealand: Auckland Is (Ocean I.), Stewart I. (Motunau I.) (Beier, 1976).

***Puffinus griseus*** (Gmelin, 1789)

CHERNETIDAE

*Apatochernes nestoris* Beier, 1962

New Zealand: North I., Bay of Plenty (Whale I.); South I., Westland (Nelson Creek, Barrytown, Murrays Mistake; Open Bay Is.); Stewart I. (Bench I.) (Beier, 1976).

PSITTACIDAE

***Anodorhynchus hyacinthinus*** (Latham, 1790)

PSEUDOSCORPIONES, unidentified species

Brazil: Mato Grosso do Sul, Pantanal de Miranda, 1 ex. in a natural nest (Dutra de Carvalho *et al.*, 2005).

***Myiopsitta monachus monachus*** (Boddaert, 1783)

CHERNETIDAE

*Parazaona bucheri* Beier, 1967

Argentina: Santa Fe, near Santa Fe City (Turienzo *et al.*, 2008).

*Parazaona morenensis* (Tullgren, 1908)

Argentina: Santa Fe, near Santa Fe City (Turienzo *et al.*, 2008).

PSEUDOSCORPIONES, undetermined species

Argentina: Buenos Aires, without detailed localities, from a total of 43 beds of fresh vegetal matter and one communal nest (Aramburú *et al.*, 2009).

***Nestor meridionalis*** (Gmelin, 1788)

CHERNETIDAE

*Apatochernes nestoris* Beier, 1962

New Zealand: North I., Bay of Plenty (Whale I.); South I., Westland (Nelson Creek, Barrytown, Murrays Mistake; Open Bay Is.); Stewart I. (Bench I.) (Beier, 1976).

PYCNONOTIDAE

***Iole olivacea*** Blyth, 1844 (= *Microscelis olivacea*: Beier, 1963).

CHERNETIDAE

*Sundochernes malayanus* Beier, 1963

Malaysia: Selangor, Rantau Panjang, 5 mi N of Klang, 28-VI-1961, 1♂ holotype [BISHOP 3465], nest 191, B.53365 (Beier, 1963).

GEOGARYPIDAE

*Geogarypus albus* Beier, 1963

Malaysia: Selangor, Rantau Panjang, 5 mi N of Klang: 22-II-1961, 1♂ paratype, nest 69, B.53013; 14-VI-1961, 1 deutonymph, paratype, nest 193, B.53338 (Beier, 1963).

***Pycnonotus goiavier*** (Scopoli, 1786)

ATEMNIDAE

*Anatemnus orites major* Beier, 1963

Malaysia: Selangor: Rantau Panjang, 5 mi N of Klang: 1960, 1♀, nest 26; 29-III-1961, 2♀, nest 110, B.53105; 19-IV-1961, 1 deutonymph, 1 tritonymph, 1♀, nest 146, B.53150 (Beier, 1963).

CHERNETIDAE

*Sundochernes malayanus* Beier, 1963

Malaysia: Selangor, Rantau Panjang, 5 mi N of Klang, 7-VI-1961, 1 tritonymph paratype, nest 182 (Beier, 1963).

GEOGARYPIDAE

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier, 1963).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang: 11-I-1961, 1♂, nest 8; 2-II-1961, 1♂, nest 50, B.52939; 5-II-1961, 1 deutonymph, nest 44, 1961-249; 9-II-1961, 2♀, nest 64; 22-II-1961, 1 protonymph, nest 56, B.53011; 22-II-1961, 1♀ (juvenile), nest 58, B-53014; 1-III-1971, 1 deutonymph, 1 tritonymph, nest 70, B-53046; 15-III-1961, 1 tritonymph, 1♂, nest 104, B.53080; 29-III-1961, 1♀ (gravid), nest 112, B.53104; 13-IV-1961, 1 tritonymph, 1♂, 1♀ (gravid), nest 142, B.53136; 7-VI-1961, 1 tritonymph, nest 197; 14-VI-1961, 1♂, 3♀, nest 190, B.53334; 14-VI-1961, 1♀, nest 200, B.53342; 14-VI-1961, 1 deutonymph, nest 204, B.53339; 21-VI-1961, 1♂, nest 212, B.53347; 21-VI-1961, 1♂, 1♀, nest 199, B.53348; 21-VI-1961, 1♀, nest 161, B.53349; 5-VII-1961, 2♂, 1♀, nest 225, B.53373; 26-VII-1961, 1♂, nest 235, B.53417 (Beier, 1963).

REMIZIDAE

***Remiz pendulinus*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817) (= *Cheridium museorum*: Krištofik *et al.*, 1995)

Slovakia: Dolny Stal, in nest with eggs (Krištofik *et al.*, 1995).

CHELIFERIDAE

*Dactylochelifer latreillei latreillei* (Leach, 1817)

Slovakia: Velké Blahovo, 1♂ in 19 examined nests (Krištofik *et al.*, 1993, 2002).

CHERNETIDAE

*Lamprochernes nodosus* (Schrank, 1803) (= *Laprochermes nodosus*: Krištofik *et al.*, 1995)

Slovakia: Jakubor, in nest with chicks (Krištofik *et al.*, 1995).

SITTIDAE

***Sitta europeae*** Linnaeus, 1758

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

STRIGIDAE

***Aegolius funereus*** (Linnaeus, 1758)

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Slovakia: Chernovrší, area of Pec, 27-VII-1993, 1♂; Škamranka, area of Postřekov, 27-VII-1993, 1 tritonymph (Krištofik *et al.*, 2003).

CHERNETIDAE

*Chernes cimicoides* (Fabricius, 1793)

Slovakia: Velká Skála, area of Postřekov, 27-VII-1993, 1♂ 1♀ (Krištofik *et al.*, 2003).

*Dinocheirus panzeri* (C. L. Koch, 1837)

Slovakia: 2♀ (Krištofik *et al.*, 2003).

***Otus asio*** (Linnaeus, 1758)

CHERNETIDAE

*Acuminochernes crassopalpus* (Hoff, 1945)

USA: New York, Siracuse, Oakwood Cemetery, 119 ex. in the material extracted from one nest (Philips & Dindal, 1990).

*Dinocheirus panzeri* (C. L. Koch, 1837)

Netherlands: Zuid-Holland, Meyendel, uit nest ransuil (Tooren, 2005).

***Otus scops*** (Linnaeus, 1758)

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

***Strix aluco*** Linnaeus, 1758

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

***Strigidae*** sp.

CHERNETIDAE

*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Chelifer panzeri*: Kew, 1911; = *Toxochernes panzeri*: Jones, 1978).

England: (Kew, 1911; Beier, 1948); Wickham, Kent, in an owl's nest (Jones, 1975, 1978).

STURNIDAE

S***turnus vulgaris*** Linnaeus, 1758

CHEIRIDIIDAE
*Cheiridium museorum* (Leach, 1817)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
Switzerland: (Lessert, 1911; Beier, 1932, 1948).

CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).
Italy: S. Vito (Modena), Emilia, nei nidi de storni (Beier, 1929b, 1948).
New Zealand: Kaikoura, Wharekiri, Donegals Flat (Beier, 1976).
Sweden: (Lohmander, 1939; Beier, 1948).

CHERNETIDAE
*Allochernes wideri* (C. L. Koch, 1843)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
*Chernes hahnii* (C. L. Koch, 1839)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Chelifer panzeri*: Kew, 1911; = *Toxochernes panzeri*: Beier, 1948; Jones, 1975).
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
England: (Kew, 1911; Beier 1948; Jones, 1975).
Sweden: (Lohmander, 1939; Beier, 1948).

NEOBISIIDAE
*Neobisium (Neobsium) sylvaticum* (C. L. Koch, 1835)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963).
*Note*: The record of this species is apparently due to a typographical error and has been implicitly corrected by Ressl (1983); it concerns nests of *Corvus corone*.

SYLVIIDAE
***Acrocephalus palustris*** (Bechstein, 1798)
NEOBISIIDAE
*Neobisium (Neobisium) inaequale* Chamberlin, 1930
Slovakia: Malacky-Vinohrádok, 12-VI-2001, 1♀, in nest; 17-VI-2001, 1♀, in nest (Krištofik *et al.*, 2005).

***Phylloscopus collybita*** (Vieillot, 1817)
NEOBISIIDAE
*Neobisium (Neobisium) sylvaticum* (C. L. Koch, 1835)
Austria: Tirol, Mutters near Innsbruck, 3-VI-1970, W. Gstader leg., 1♂, 3♀, V. Mahnert det.

***Sylvia atricapilla*** (Linnaeus, 1758) (= *Parus atricapillus*: Nordberg, 1936).
CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

*Dactylochelifer latreillei latreillei* (Leach, 1817)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936) (mis-identified, see *Chernes cimicoides*). Chernetidae

CHERNETIDAE
*Chernes cimicoides* (Fabricius, 1793) and *Dinocheirus panzeri* (C. L. Koch, 1837)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936). The samples determined as *D. latreillei* consist of individuals of two other species, *Chernes cimicoides* and *Toxochernes (= Dinocheirus) panzeri* (Kaisila, 1949).

***Sylvia borin*** (Boddaert, 1783)
CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936)

TETRAONIDAE
***Tetrao urogallus*** Linnaeus, 1758
NEOBISIIDAE
*Neobsium (Neobisium) crassifemoratum* (Beier, 1928)
Slovakia: (Fenda *et al.*, 1998).

TROGLODYTIDAE
***Troglodytes musculus*** Neumann, 1823
CHERNETIDAE
*Calidiochernes musculi* Beier, 1957
Venezuela: Llanos, nest of *Troglodytes musculus* ("cucaracharo") (Beier, 1957a).

***Troglodytes troglodytes*** (Linnaeus, 1758)
NEOBISIIDAE
*Neobisium (Neobisium) carcinoides* (Hermann, 1804)
Slovakia: (Fenda *et al.*, 1998).

***Thryothorus leucotis*** Lafresnaye, 1845
CHTHONIIDAE
*Pseudochthonius homodentatus* Chamberlin, 1929
Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58° 40'W, VII/XII-2000, 1 nymph in nest # 1 of a total of 8 examined nests (Torres, 2001).
*Tyrannochthonius migrans* Mahnert, 1979
Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 1 ♀ in nest # 1 of a total of 8 examined nests (Torres, 2001).

IDEORONCIDAE
*Xorilbia* cf. *gracilis* (Mahnert, 1985) (= *Albiorix* sp. cf. *gracilis*: Torres, 2001).

Brazil: Amazonas: Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 1 nymph in nest # 5 of a total of 8 examined nests (Torres, 2001).

OLPIIDAE

*Pachyolpium irmgardae* Mahnert, 1979

Brazil: Amazonas, Municipios Silves & Itacotiara, Mil Madereira Itacotiara Ltda., 3°00'S, 58°40'W, VII/XII-2000, 2 nymphs in one nest of a total of 8 examined nests (Torres, 2001).

TURDIDAE

***Phoenicurus ochruros gibraltariensis*** (Gmelin, 1789)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Europe: (Roewer, 1937; Beier, 1948).

***Phoenicurus ochruros*** (Gmelin, 1789) (= black redstart: Ranius & Wilander, 2000).

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)

Austria: Lower Austria, Scheibbs Distr. (Ressl & Beier, 1958; Ressl, 1963, 1983).

France: Haute-Savoie, Bossy-sur-Frangy, VIII-1983, leg. J. Steffen, 2♂, det. V. Mahnert.

Switzerland: canton of Vaud, Commugny, 29-IX-1963, leg. J. Steffen, 4♂, 5♀, det. V. Mahnert.

LARCIDAE

*Larca lata* (Hansen, 1884)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1965, 1983).

***Phoenicurus phoenicurus*** (Linnaeus, 1758)

CHEIRIDIIDAE

*Cheiridium museorum* (Leach, 1817)

Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

CHERNETIDAE

*Allochernes wideri* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl & Beier, 1958; Ressl, 1963, 1983).

*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Dinocheirus panzeri panzeri*: Ressl, 1983; = *Dinocheirus panzeri rufeolus*: Ressl, 1983).

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963, 1983).

***Sialia*** sp.

CHERNETIDAE

*Parachernes squarrosus* Hoff, 1949
USA: Illinois, Quincy, in bluebird box (Hoff, 1949).

***Turdus merula*** Linnaeus, 1758
CHTHONIIDAE
*Chthonius (Ephippiochthonius) fuscimanus* Simon, 1900
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).
*Chthonius (Chthonius) ischnocheles* (Hermann, 1804)
England: Newcastle-upon-Tyne (Jones, 1975).
*Tyrannochthonius kermadecensis* (Beier, 1976) (= *Paraliochthonius kermadecensis*: Beier, 1976).
New Zealand: Kermadec Is., in deserted nest (Beier, 1976).

CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).
*Dactylochelifer latreillei latreillei* (Leach, 1817)
Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

CHERNETIDAE
*Dinocheirus panzeri* (C. L. Koch, 1837) (= *Dinocheirus panzeri rufeolus*: Ressl, 1983).
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

NEOBISIIDAE
*Neobisium (Neobisium) sylvaticum* (C. L .Koch, 1835)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1983).

***Turdus philomelas*** Brehm, 1831
CHELIFERIDAE
*Dactylochelifer latreillei latreillei* (Leach, 1817)
Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

***Turdus pilaris*** Linnaeus, 1758
CHEIRIDIIDAE
*Cheiridium museorum* (Leach, 1817)
Finland: Aland (? Tvärminne or Helsingfors) (Nordberg, 1936).

***Turdus*** sp.
CHTHONIIDAE
*Chthonius (Ephippiochthonius) tetrachelatus* (Preyssler, 1790)
Czech Republic: Prague, Zavadilova ul., nest of *Turdus* sp. (Stahlavsky, 2001).

TYRANNIDAE
***Sayornis phoebe*** (Latham, 1790)
CHELIFERIDAE

*Chelifer cancroides cancroides* (Linnaeus, 1758)
North America: (Beier, 1948).

TYTONIDAE
***Tyto alba*** (Scopoli, 1769)
CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
France: Haute-Savoie, Bossy-sur-Frangy, 450m, among pellets, 1983-1984, leg. J. Steffen, 5♂, 15♀ 1 trito-, 1 deutonymph, det. V. Mahnert.
Switzerland: Genève, Jussy-Monniaz, "Les Gressevaux", among barn owl pellets, 1976, leg. M. Jaussi, 1♀, det. V. Mahnert.
LARCIDAE
*Larca lata* (Hansen, 1884)
Netherlands: Gelderland, Vorchten (Heerde), loft of a church, among barn owl pellets (Tooren, 2001).

UPUPIDAE
***Upupa epops*** Linnaeus, 1758
CHERNETIDAE
*Pselaphochernes scorpioides* (Hermann, 1804)
Slovakia: (Christophoryova & Krumpalova, 2010).

UNIDENTIFIED FAMILIES: Nests and guano in colonies of unidentified birds
ATEMNIDAE
*Diplotemnus insularis* Chamberlin, 1933
Brazil: St. Paul's Rocks (Arquipélago de São Pedro e São Paulo), 0°55'10"N/29°20'33"W, (Atlantic Ocean), in bird nests and on birds (Chamberlin, 1933; Beier, 1940, 1948).
*Note*: Three species of sea birds are breeding on the islets of this archipelago: *Sula leucogaster* (Pelcaniformes, Sulidae), *Anous stolidus* and *A. minutus* (Charadriiformes, Laridae) (Edwards, 1979).
CHEIRIDIIDAE
*Apocheiridium rossicum* Redikorzev, 1935
Russia: Ural Mts, Perm, on unidentified bird (Redikorzev, 1938).
*Cheiridium museorum* (Leach, 1817)
England: (Kew, 1911, Beier, 1948); Belton, Leicestershire, in old bird's nest (Robin/house sparrow?) in dry stone wall (Jones, 1975).
Germany: "Ostdeutschland", in birds' nests (Drogla & Lippold, 2004)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).
CHELIFERIDAE
*Chelifer cancroides cancroides* (Linnaeus, 1758)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).

*Dactylochelifer latreillei latreillei* (Leach, 1817)
Slovakia: (Krumpal & Cyprich, 1988).
*Paisochelifer callus* (Hoff, 1945)
USA: eastern and central USA, in birds' nests (Muchmore, 1990).

CHERNETIDAE
*Allochernes wideri* (C. L. Koch, 1843)
Austria: (Beier, 1932; Beier, 1948); Lower Austria, Scheibbs Distr. (Ressel, 1963).
Germany: in birds' nests (Schenkel, 1928); Bayern, Aschaffenburg, "in Nestern von Höhlenbrütern" (Helversen, 1966); "Ostdeutschland", in birds' nests (Drogla & Lippold, 2004).
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).
Sweden: Östergötland: in 40.9% of hollow oaks with bird nests (Ranius & Wilander, 2000).
*Chernes cimicoides* (Fabricius, 1793)
Slovakia: (Krumpal & Cyprich, 1988).
*Chernes hahnii* (L. Koch, 1873)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).
*Chernes vicinus* (Beier, 1932) (= *Allochernes vicinus*: Krumpal & Cyprich, 1988).
Slovakia: (Krumpal & Cyprich, 1988).
*Chernes* sp.
England: frequently in nests, often in very large numbers (Woodroffe, 1953).
Slovakia: (Krumpal & Cyprich, 1988).
*Dendrochernes cyrneus* (L. Koch, 1878)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).
*Dinocheirus panzeri* (C. L. Koch, 1937)
Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963).
Netherlands: Zuid-Holland, Meyendel, uit divers nest-materiaal (Tooren, 2005).
Slovakia: (Krumpal & Cyprich, 1988).
*Hesperochernes montanus* Chamberlin, 1935
USA: Montana, Girds Creek, Ravalli County, in a bird's nest (Chamberlin, 1935).
*Lamprochernes chyzeri* (Tömösvary, 1882)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).
*Lamprochernes nodosus* (Schrank, 1761)
Slovakia: (Krumpal & Cyprich, 1988; Christophoryova & Krumpalova, 2010).

*Neochelanops patagonicus* (Tullgren, 1900)

Argentina: Santiago del Estero, Añatuya, in birds' nests, identified by Feio [MNRJ] (Mazza, 1943).

*Note*: This locality is mentioned in Feio (1945) as "Añatinga", an error repeated by Ceballos & Rosso de Ferradás (2008).

*Opsochernes carbophilus* Beier, 1966

New Zealand: Occasionally in bird nests (Beier, 1976).

*Parachernes* cf. *argentinus* Beier, 1967

Argentina: [locality not specified], in birds' nests [not specified] (Turienzo *et al.*, 2008).

*Pselaphochernes scorpioides* (Hermann, 1804)

Austria: (Beier, 1948).

CHTHONIIDAE

*Chthonius (Ephippiochthonius) tetrachelatus* (Preyssler, 1790)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963).

Slovakia: (Krumpal & Cyprich, 1988).

*Chthonius* sp.

Slovakia: (Krumpal & Cyprich, 1988).

GARYPIDAE

*Garypus titanius* Beier, 1961

Ascension Island: Bos'nbird Isle, "im Vogelguano der Nistkolonien" [in birds's guano of the nesting colony], 13 species of sea birds (Beier, 1961).

GEOGARYPIDAE

*Geogarypus albus* Beier, 1963

Malaysia: Selangor, Rantau Panjang, 5 mi N of Klang, 1960, ♂ holotype, nest # 65, from same locality, 1960, ♀ allotype [BISHOP], nest # 62, 1960, 1♀ paratype, nest # 26, 1960, 1♂ paratype, nest # 111 (Beier, 1963).

*Geogarypus longidigitatus* (Rainbow, 1897) (= *Geogarypus elegans audyi* Beier, 1952: Beier 1963).

Malaysia: Selangor, Rantau Panjang, 8 km N of Klang, 1960, 1 deutonymph, 1 tritonymph, nest # 231; 1960, 1 tritonymph, 3♂♂, nest # 255; 1960, 1 deutonymph, nest # 257; 1960, 1 deutonymph, nest # 256; 1960, 1♀ (gravid), nest # 270; 1960, 1 tritonymph, nest # 274; 13-VII-1960, 1♀, nest # 282; 1960, 1 tritonymph, nest # 290; 5-X-1960, 1 protonymph, nest # 317 (Beier, 1963).

LARCIDAE

*Larca lata* (Hansen, 1884)

Slovakia (and/or Austria-Czech Republic): (Christophoryova & Krumpalova, 2010).

Sweden: province of Östergötland, in hollow oaks with bird nests (Ranius & Wilander, 2000).

NEOBISIIDAE

*Neobisium (Neobisium) carcinoides* (Hermann, 1804) (= *Neobisium muscorum*: Chater, 1989; Krumpal & Cyprich, 1988).

Slovakia: (Krumpal & Cyprich, 1988; Fenda *et al.*, 1998: nest type *Motacilla*; Christophoryova & Krumpalova, 2010).

United Kingdom: Wales, Ceredigion, found in birds' nests on the ground (Chater, 1989).

*Neobisium (Neobisium) crassifemoratum* Beier, 1928

Slovakia: (Krumpal & Cyprich, 1988).

*Neobisium (Neobisium) inaequale* Chamberlin, 1930

Slovakia: (Krumpal & Cyprich, 1988; Fenda *et al.*, 1998: nest type *Motacilla*).

*Neobisium (Neobisium) sylvaticum* (C. L. Koch, 1843)

Austria: Lower Austria, Scheibbs Distr. (Ressl, 1963).

OLPIIDAE

*Xenolpium pacificum pacificum* (With, 1907)

New Zealand: (Beier, 1976).

PSEUDOGARYPINIDAE

*Pseudogarypinus frontalis* (Banks, 1909)

USA: western United States, in birds' nests (Muchmore, 1990).

WITHIIDAE

*Dolichowithius argentinus* Beier, 1959

Argentina: [province, locality not specified] in birds' nests [not specified] (Turienzo *et al.*, 2008).

*Dolichowithius* cf. *argentinus* Beier, 1959

Argentina: [province, locality not specified] in birds' nests [not specified] (Turienzo *et al.*, 2008).

*Stenowithius duffeyi* Beier, 1961

Ascension Island: Bos'nbird Isle, "auf dem Vogelguano der Nistkolonien" [on the birds' guano in the nesting colony"] (13 species of sea birds) (Beier, 1961).

PSEUDOSCORPIONES, undetermined species

Argentina: Salta, Dto Santa Bárbara, in the proximities of the river Lavayen, together with *Psammolestes coreodes* (Bergroth, 1911) [Hemiptera: Reduviidae: Triatominae] (Mazza, 1943).

India: West Bengal, 788 adult pseudoscorpions in 1536 nests of 8 species of birds [*Streptopelia chinensis* (Scopoli); *Acridotheres tristis* (Linnaeus); *Sturnus contra* Linnaeus; *Corvus splendens* Vieillot; *Prinia socialis* Sykes; *Ploceus philippinus* (Linnaeus); *Passer domesticus* (Linnaeus)] (Bhattacharyya, 1990).

USA: Florida, in poultry manure (Propp & Morgan, 1985).

## DISCUSSION

14 families of pseudoscorpions with 63 genera and 85 species are recorded from birds' nests. Chernetidae are dominant with 22 genera and 35 species, these numbers represent about 19% of the described genera and 5% of the described species in this family (Harvey, 2009). It is followed by Chthoniidae (5 genera/subgenera and 9 species) (= about 1.3% of the described species), Cheliferidae (5 genera and 6 species/subspecies) (=about 8% of the decribed genera and about 2% of the described species!), Olpiidae (4 genera and 4 species), Withiidae (4 genera and 7 species) (= about 11% of the described genera and 4.5% of the described species!), Atemnidae (4 genera and 5 species/subspecies), Cheiridiidae (2 genera and 5 species), Neobisiidae and Geogarypidae (1 genus and 4 species each), Larcidae (1 genus and 2 species), Garypidae, Ideoroncidae, Pseudogarypinidae (1 species each), Syarinidae (1 species). The predominance of Chernetidae might be explained partly by the corticolous biology of many of its species.

45 families of birds have been recorded, represented by a total of 98 identified species and a certain number of unidentified taxa, a very small part compared to the number of species and families recognized world-wide (about 142 families and 9700 species). The ranking is headed by Procellariidae, Turdidae (7 spp.) each, Furnariidae (6 or 5 spp.), Hirundinidae (5 spp.), Picidae, Sylviidae (4 spp. each), Strigidae (4 spp.), Anatidae, Cacatuidae, Corvidae, Estrildidae, Laniidae, Paridae, Psittacidae, Troglodytidae (3 spp. each), Anatidae, Passeridae (3 spp. each), Apodidae, Ardeidae, Cisticolidae, Columbidae, Laridae, Motacillidae, Muscicapidae, Phasianidae, Pycnonotidae (2 spp. each), Accipitridae, Cinclidae, Climacteridae, Coraciidae, Emberizidae, Formicariidae, Fringillidae, Halcyonidae, Icteridae, Meropidae, Nectariidae, Panuridae, Phalacrocoracidae, Remizidae, Sittidae, Sturniidae, Tetraonidae, Tyrannidae, Tytonidae, and Upupidae (1 sp. each). Easy accessibility of nests for human observers explains probably the predominance of certain families.

Little information can be gathered from listing pseudoscorpions and birds'nests per country. That reflects only the interest of collectors in the mentioned countries, or particular interest in other arthropod groups present in birds' nests. This fact is emphasized by the leading position of Austria (17 bird species studied, but compare this to the over 200 bird species breeding in Austria!) which is almost exclusevily due to the activity of one single person, Franz Ressl from the Scheibbs District, Lower Austria. The prominence of Slovakia is due to a research program initiated mainly by J. Kristofik, and the many data from Malaysia are the results of the collecting by H. E. McClure and Lim Boo-Liat (Beier, 1963, 1964). From some European countries we do not have any record (e.g. Spain, Belgium, Greece, etc.). Several countries in tropical areas (i.e. Brazil, Venezuela, India, Uganda) have very few records of pseudoscorpions from birds' nests. A similar situation was presented for the insect fauna in birds' nests from the Neotropical Region (Di Iorio & Turienzo, 2009). Furthermore, it can be pointed out that indications of origin in older collections were sometimes incomplete, without any information on habitats (see *Parazaona bucheri* and *Parachernes argentinus* under *Phacellodomus* sp.).

The presence of pseudoscorpions in birds' nests is certainly favoured by good or optimal living conditions offered by this particular niche: abundance of potential

prey (mites, larvae of various insects, e.g. fleas and dipteras, in the nests, biting lice (Mallophaga) directly on the birds), and also microclimatic conditions without large variation in humidity, temperature and light (nests in hollow trees) (see Krumpal & Cyprich, 1988 and Christophoryova & Krumpalova, 2010).

It is evident that the building site of nests highly influences the presence of one or another pseudoscorpion family. Nests built on the ground will be visited mainly by soil-dwelling genera and species, e.g. Chthoniidae (genera *Chthonius*, *Tyrannochthonius*), Neobisiidae (*Neobisium*), Olpiidae, Geogarypidae and, to a lesser extent, Garypidae and Syarinidae or even Withiidae (animals of this family are found in litter or under stones, but also under the bark of living or fallen trees). *Mundochthonius styriacus* (Chthoniidae) and *Anthrenochernes stellae* (Chernetidae) seem to prefer the constant conditions of hollow trees and are therefore frequently found in birds' nests constructed in this habitat. On the other hand, many species of usually bark-inhabiting families (Cheiridiidae, Chernetidae, Cheliferidae) are regularly colonizing nests in trees, but the presence of several genera, e.g. *Dactylochelifer* (Cheliferidae), *Apatochernes*, *Chelanops*, *Chernes* or *Sundochernes* (Chernetidae) is common, though probably not very frequent. Biology is explaining the sporadic presence of the tritonymph of *Neobisium sylvaticum* in nests in trees: this stage frequently climbs on shrubs and trees (Beier, 1963b) and arrives accidentally in nests. Some species of Cheiridiidae (*Apocheiridium* spp., *Cheiridium museorum*), Cheliferidae (*Chelifer cancroides*) and Chernetidae (*Dinocheirus panzeri*) are regularly colonizing nests of synanthropic birds (e.g. *Columba livia*, *Passer domesticus*, *Gallus gallus*) or may be passively dispersed by other birds (e.g. *Larca lata* by *Phoenicurus ochrurus*: Ressl, 1963b, 1965).

The abundance of pseudoscorpions is usually low (particularly in most ground nests), but may be very high in old nests in the nature, and even more so in nests of synanthropic bird species.

Only a few species can be considered as (more or less) exclusive colonizers of tree nests of birds, as far as we can judge from the scarce surveys and collecting data. These are *Diplotemnus insularis* Chamberlin (St Paul's Islands), *Hesperochernes montanus* (USA) (Beier, 1948), *Troglochernes dewae* (Australia) (Harvey & Volschenk, 2007), *Parazaona bucheri*, *Parazaona morenensis* (Turienzo, Di Iorio & Mahnert, unpublished data) and *Calidiochernes musculi* (South America) (Beier, 1957). On the other hand, some common bark-inhabiting species of the genera *Victorwithius* and *Dolichowithius* (Withiidae from South America) have never or very rarely been found in birds' nests. Even more surprising is the quasi total absence in nests of some Atemnidae, e.g. *Paratemnoides nidificator* (Balzan), *P. pallidus* (Balzan), and *P. elongatus* (Banks). These species show evidence of social behaviour and can be found in huge numbers under the bark of standing or fallen trees.

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## REFERENCES

NOTE: The authors (V. M. in particular) would appreciate to receive complementary information and/or missed references dealing with the presence of pseudoscorpions in birds' nests. Two references apparently citing pseudoscorpions in association with birds should be omitted from such a bibliographic list: George (1989) (p. 337: "Contrary to my usual experience I saw no....pseudoscorpions"), and Barreto & Carvalheiro (1967) (p. 18: "...artropodos predatores, como...escorpiônidas...").

ADIS, J. 1979. Vergleichende ökologische Studien an der terrestrischen Arthropodenfauna zentralamazonischer Überschwemmungsdwälder. *Dissertation Ph.D., Universität Ulm*, 99 pp.

ADIS, J. 1992. Überlebenstrategien terrestrischer Invertebraten in Überschwemmungswäldern Zentralamazoniens. *Verhandlungen des Naturwissenschaftlichen Vereins in Hamburg* (NF) 33: 21-114.

ADIS, J. & MAHNERT, V. 1985. On the natural history and ecology of Pseudoscorpiones (Arachnida) from an Amazonian blackwater inundation forest. *Amazoniana* 9(3): 297-314.

ADIS, J. & MAHNERT, V. 1990. On the species composition of Pseudoscorpiones from Amazonian dryland and inundation forests in Brazil. *Revue suisse de Zoologie* 97: 49-53.

AMERICAN ORNITHOLOGISTS' UNION 1998. Check-list of North American Birds. 7th Edition. *American Ornithologists' Union, Washington DC*, 829 p.

ARAMBURU, R., CALVO, S., CARPINTERO, D. L. & CICCHINO, A. C. 2009. Artrópodos presentes en nidos de cotorra *Myiopsitta monachus monachus* (Aves: Psittacidae). *Revista del Museo Argentino de Ciencias Naturales* (nueva serie) 11(1): 1-5.

BARRETO, M., BARRETO, P. & D'ALESSANDRO, A. 1984. *Psammolestes arthuri* (Hemiptera: Reduviidae) and its parasite Telenomus capito (Hymenoptera: Scelionidae) in Colombia. *Journal of Medical Entomology* 21(6): 703-705.

BARRETO, M. P. & CARVALHEIRO, J. 1967. Estudos sobre reservatórios silvestres do *Trypanosoma cruzi*. XVIII. Observações sobre a ecologia do Psammolestes tertius, Lent & Jurbert, 1965 (Hemiptera-Reduviidae). *Revista brasileira de Biologia* 27: 13-25.

BEIER, M. 1929a. Die Pseudoskorpione des Wiener Naturhistorischen Museums. II. Panctenodactyli. *Annalen des Naturhistorischen Museums in Wien* 42: 341-367.

BEIER, M. 1929b. Alcuni Pseudoscorpioni raccolti da C. Menozzi. *Bollettino della Società entomologica italiana* 61: 154-156.

BEIER, M. 1932. Pseudoscorpionidea II. Subord. C. Cheliferinea. *Das Tierreich* 58: I-XXI, 1-294.

BEIER, M. 1940. Die Pseudoscorpionidenfauna der landfernen Inseln. *Zoologische Jahrbücher, Systematik (Ökologie), Geographie und Biologie* 74: 161-192.

BEIER, M. 1948. Phoresie and Phagophilie bei Pseudoscorpionen. *Österreichische zoologische Zeitschrift* 1(5): 441-497.

BEIER, M. 1957a. Eine Pseudoscorpioniden-Ausbeute aus Venezuela. *Memorie del Museo Civico di Storia Naturale di Verona* 4: 131-142.

BEIER, M. 1957b. Los insectos de las Islas Juan Fernandez 37. Die Pseudoscorpioniden-Fauna der Juan-Fernandez-Inseln (Arachnida Pseudoscorpionida). *Revista Chilena de Entomologia* 5: 451-464.

BEIER, M. 1961. Pseudoscorpione von der Insel Ascension. *Annals and Magazine of Natural History* (13)3: 593-598.

BEIER, M. 1963a. Pseudoscorpione aus Vogelnestern von Malaya. *Pacific Insects* 5(3): 507-511.

BEIER, M. 1963b. Ordnung Pseudoscorpionidea (Afterskorpione). *Bestimmungsbücher der Bodenfauna Europas* 1: I-VII, 1-313.

BEIER, M. 1964. Some further nidicolous Chelonethi (Pseudoscorpionidea) from Malaya. *Pacific Insects* 6(2): 312-313.

BEIER, M. 1967. Zwei neue Chernetiden (Pseudoscorp.) von Argentinien. *Annalen des Naturhistorischen Museums in Wien* 70: 95-98.

BEIER, M. 1971. Ein neuer *Mundochthonius* (Arachnida, Pseudoscorpionidea) aus der Steiermark. *Mitteilungen des Naturwissenschaftlichen Vereins für Steiermark* 100: 383-387.

BEIER, M. 1976. The pseudoscorpions of New Zealand, Norfolk, and Lord Howe. *New Zealand Journal of Zoology* 3: 199-246.

BENEDICT, E. M. & MALCOLM, D. R. 1979. Pseudoscorpions of the family Cheliferidae from Oregon (Pseudoscorpionida, Cheliferoidea). *Journal of Arachnology* 7: 187-198.

BENEDICT, E. M. & MALCOLM, D. R. 1982. Pseudoscorpions of the family Chernetidae newly identified from Oregon (Pseudoscorpionida, Cheliferoidea). *Journal of Arachnology* 10: 97-109.

BHATTACHARYYA, S. 1990a. A survey of pseudoscorpions in the nests of *Passer domesticus* (Linnaeus) in West Bengal. *Environmental Ecology* (Kalyan) 8(1B): 245-247.

BHATTACHARYYA, S. 1990b. Factors controlling growth of arthropod fauna in the nests of birds. *Environment & Ecology* (Kalyan) 8(2): 626-629.

BHATTACHARYYA, S. 1999. New records of arthropods associated with the birds' nests in India. *Environment & Ecology* (Kalyan) 17(3): 685-692.

BUCHER, E. H. 1974. Observaciones ecologicas sobre los artropodos del bosque chequeño de Tucumán. *Revista de la Facultad de Ciencias Exactas, Físicas y Naturales de Córdoba* (nueva serie), Biología 1: 35 122.

CARCAVALLO, R., OTERO, M. A., TONN, R. I. & ORTEGA, R. 1975. Notas sobre la biología, ecología y distribución geográfica de *Psammolestes arthuri* (Pinto) 1926 (Hemiptera, Reduviidae). Descripción de los estadios imaginales. *Boletín Informativo de la Dirección de Malariología y Saneamiento Ambiental* 15(5): 231-239.

CEBALLOS, A. & ROSSO DE FERRADAS, B. 2008. Pseudoscorpiones. In: CLIPS, L. E., DEBANDI, G. & ROIG-JUNENT, S. (eds): *Biodiversidad de Artropodos Argentinos* 2: 105-116.

CHAMBERLIN, J. C. 1933. Scorpions of the atemnid subfamily Miratemninae. *Annals of the entomological Society of America* 26: 262-268.

CHAMBERLIN, J. C. 1935. A new species of false scorpion (*Hesperochernes*) from a bird's nest in Montana. *Pan-Pacific Entomology* 11: 37-39.

CHATER, A. O. 1989. Pseudoscorpiones. False-scorpions in Ceredigion, vc 46. *Dyfed Invertebrate Group, Newsletter* (14): 5-10.

CHRISTOPHORYOVA, J. & KRUMPALOVA, Z. 2010. Pseudoscorpions in the nests of birds (p. 108-109), and poster. In: ZABKA, M. (ed.). Book of Abstracts, 18th International Congress of Arachnology, 11-17 July 2010. *Siedlce, Poland*, 1-506.

COMITÊ BRASILEIRO DE REGISTROS ORNITOLÓGICOS 2007. Lista das aves do Brasil. 6ª edição (16 de agosto de 2007). *Sociedade Brasileira de Ornitologia*. Available from *http://www.cbro.org.br* (accessed IV. 2010).

DI IORIO, O. & TURIENZO, P. 2009. Insects found in birds' nests from the Neotropical Region (except Argentina) and inmigrant species of Neotropical origin in the Nearctic Region. *Zootaxa* 2187: 1-144.

DI IORIO, O., TURIENZO, P., NAVA, S., MASTROPAOLO, M., MANGOLD, A.J., GONZÁLEZ ACUÑA, D. & GUGLIELMONE, A. A. 2010. *Asthenes dorbignyi* (Reinchenbach) (Passeriformes: Furnariidae) host of *Argas neghmei* Kohls & Hoogstraal, 1961 (Acari: Argasidae). *Experimental and Applied Acarology* doi: 10.1007/s10493-009-9333-4.

DROGLA, R. & LIPPOLD, K. 2004. Zur Kenntnis der Pseudoskorpion-Fauna Ostdeutschlands (Arachnida, Pseudoscorpiones). *Arachnologische Mitteilungen* 27/28: 1-54.

DUTRA DE CARVALHO, T., GUEDES, N. M. R. & FAVERO, S. 2005. Artropodofauna associada a ninhos de Arara Azul no Pantanal de Miranda, Mato Grosso do Sul, Brasil. *Bio(in)formação, Monografias Ciências Biológicas* 2005: 100-112.

EDWARDS, A. 1979. General report of the Cambridge Expedition to Saint Paul's Rocks. *Cambridge Expedition to Saint Paul's Rocks* (Cambdridge): 1-32.

ELLINGSEN, E. 1911. Pseudoscorpionina. In: LE ROI, O. (ed.). Zur Fauna des Vereinsgebietes. *Sitzungsberichte herausgegeben vom Naturhistorischen Verein der Preussischen Rheinländer und Westfalens* 1911: 173-174.

ELLINGSEN, E. 1912. The pseudoscorpions of South Africa based on the collections of the South African Museum, Cape Town. *Annales of the South African Museum* 10: 75-128.

ELLINGSEN, E. 1913. Note on some pseudoscorpions in the British Museum. *Annals and Magazine of Natural History* (8) 11: 451-455.

ELLINGSEN, E. 1914. On the pseudoscorpions of the Indian Museum. *Records of the Indian Museum* 10(1): 1-14.

FEIO DE ARAUJO, J. L. 1945. Novos pseudoscorpiões de região Neotropical (com a descrição de ume subfamilia, dois generos e sete especies). *Boletim do Museu National Rio de Janeiro, Zoologia*, 44: 1-47.

FENDA, P., KRUMPAL, M. & CYPRICH, D. 1998. The soil fauna in the birds' nests in Slovakia (p. 23-30). In: PIZL, V. & TAJOVSKY, K. (eds). Soil zoological problems in central Europe. Proceedings of the 4th Central European Workshop on Soil Zoology held in Ceske Budejovice, Czech Republic, April 23-24, 1997. *Institute of Soil Biology, Academy of Sciences of the Czech Republic.*

GÄRDENFORS, U. & WILANDER, P. 1995. Ecology and phoretic habits of *Anthrenochernes stellae* (Pseudoscorpionida, Chernetidae). *Bulletin of the British arachnological Society* 10(1): 28-30.

GEORGE, R. S. 1961. More records of Gloucestershire false-scorpions. *Report of the North Gloucestershire Naturalists' Society* 1959-60: 38.

GEORGE, R. S. 1989. Large populations of fleas (Siphonaptera) in birds' nests and a species new to England. *Entomologist's Gazette* 40: 337-343.

GRIMALDI, P., STORACCIO, S. C. & CEBALLOS, A. 2006. Datos preliminares del comportamiento de apareamiento, morfología genital y dimorfismo sexual de *Parachernes (Parachernes)* cf. *pulcher* Mahnert, 1979 (Pseudoscorpiones, Chernetidae) (p. 40). *Primeras Jornadas de Comportamiento Animal. Montevideo, Uruguay, 30 de Noviembre y 1 de Diciembre de 2006.*

HARVEY, M. S. 2009. Pseudoscorpions of the world. Version 1.2. *Western Australian Museum Perth*. Available from *http://www.museum.wa.gov.au/arachnids/pseudoscorpions* (accessed VI. 2010).

HARVEY, M. S. & VOLSCHENK, E. S. 2007. A review of some Australasian Chernetidae: *Sundochernes*, *Troglochernes* and a new genus (Pseudoscorpiones). *Journal of Arachnology* 35: 238-277.

HELVERSEN, O. VON 1966. Pseudoskorpione aus dem Rhein-Main-Gebiet. *Senckenbergiana biologica* 47(2): 131-150.

HOFF, C. C. 1944. Notes on three pseudoscorpions from Illinois. *Illinois Academy of Science Transactions* 37: 123-128.

HOFF, C. C. 1949. The pseudoscorpions of Illinois. *Bulletin of the Illinois Natural History Survey* 24(4): 411- 498.

HOFF, C. C. 1957. *Tejachernes* (Arachnida-Chelonethida, Chernetidae-Chernetinae), a new genus of pseudoscorpion based on *Dinocheirus stercoreus*. *The Southwestern Naturalist* 2(2-3): 83-88.

HOFF, C. C. 1961. Pseudoscorpions from Colorado. *Bulletin of the American Museum of Natural History* 122 (5): 409-464.

HULLEY, P. E. 1983. A survey of the flies breeding in poultry manure, and their potential natural enemies. *Journal of the Entomological Society of Southern Africa* 46: 37-47.

JELLISON, W. M. I. & PHILIP, C. P. 1933. Faunae of nests of the magpie and crow in western Montana. *The Canadian Entomologist* 65: 26-31.

JONES, P. E. 1975. The occurrence of pseudoscorpions in the nests of British birds. *Proceedings of the British entomological and Natural History Society* 1975: 87-89.

JONES, P. E. 1978. Phoresy and commensalism in British pseudoscorpions. *Proceedings of the British entomological and Natural History Society* 1978: 90-96.

JOST, G. 1982. Zur Vorkommen und zur Verbreitung von Pseudoskorpionen (Arachnida, Pseudoscorpionidea) im Naturpark Hoher Vogelsberg. *Hessische faunistische Briefe* (Darmstadt) 2: 2-12.

KAISILA, J. 1949. A revision of the pseudoscorpion fauna of eastern Fennoscandia. *Suomen Hyönteistieteellinen Aikakauskirja* 15(2): 72-92.

KEW, H. W. 1911. A synopsis of the false-scorpions of Britain and Ireland. *Proceedings of the Royal Irish Academy* (B)29: 38-64.

KRISTOFIK, J., MASAN, P. & ŠUSTEK, Z. 1996. Ectoparasites of bee-eater (*Merops apiaster*) and arthropods in its nests. *Biologia* (Bratislava) 51(5): 557-570.

KRISTOFIK, J., MASAN, P. & ŠUSTEK, Z. 2005. Arthropods in the nests of marsh warblers (*Acrocephalus palustris*). *Biologia* (Bratislava) 60(2): 171-177.

KRISTOFIK, J., MASAN, P. & ŠUSTEK, Z. 2007. Arthropods (Pseudoscorpionidea, Acarina, Coleoptera, Siphonaptera) in nests of the bearded tit (*Panurus biarmicus*). *Biologia* (Bratislava), 62(6): 749-755.

KRISTOFIK, J., MASAN, P., ŠUSTEK, Z. & GAJDOS, G. 1993. Arthropods in the nests of penduline tit (*Remiz pendulinus*). *Biologia* (Bratislava) 48(5): 493-505.

KRISTOFIK, J., MASAN, P., ŠUSTEK, Z. & KLOUBEC, B. 2003. Arthropods (Pseudoscorpionida, Acari, Coleoptera, Siphonaptera) in nests of the tengmalm's owl, *Aegolius funereus*. *Biologia* (Bratislava) 58(2): 231-240.

KRISTOFIK, J., ŠUSTEK, Z. & GAJDOS, G. 1994. Arthropods in nests of the Sand Martin (*Riparia riparia* Linnaeus, 1758) in South Slovakia. *Biologia* (Bratislava) 49(5): 683-690.

KRISTOFIK, J., ŠUSTEK, Z. & GAJDOS, G. 1995. Arthropods in the penduline tit (*Remiz pendulinus*) nests: occurrence and abundance in different breeding phases. *Biologia* (Bratislava) 50: 487-493.

KRISTOFIK, J., ŠUSTEK, Z. & MASAN, P. 2002. Arthropods (Pseudoscorpionida, Acari, Coleoptera, Siphonaptera) in the nests of red-backed shrike (*Lanius collurio*) and lesser grey shrike (*Lanius minor*). *Biologia* (Bratislava) 57(5): 603-613.

KRUMPAL, M. & CYPRICH, D. 1988. O výskyte štúrikov (Pseudoscorpiones) v hniezdach vtákov (Aves) v podmienkach Slovenska. *Zbornik Slovenského narodneho Muzea, Prorodnó vedy* 34: 41-48.

LEGG, G. & O'CONNOR, J. P. 1997. A review of the Irish pseudoscorpions (Arachnida: Pseudoscorpiones). *Irish Biogeographical Society Bulletin* 20: 105-126.

LENT, H. 1939. Relatório da excursão científica do Instituto Oswaldo Cruz realizado na zona da Estrada de Ferro Noroeste do Brasil. IV. Observações sôbre a fauna de alguns ninhos de aves. *Boletim Biologico de la Facultad de Medicina do São Paulo* (nova série) 4(2): 258-260.

LESSERT, R. DE 1911. Pseudoscorpions. *Catalogue des Invertébrés de la Suisse* 5: 1-50.

LINS DUARTE, P. F. 1978. Aranhas encontradas em ninhos de *Phacellodomus rufifrons specularis* (Hellmayr, 1925) (Aves, Passeriformes, Furnariidae) – I. *Revista Nordestina de Biología* (Universidade Federal da Paraiba, Departamento de Biología) 1(1): 55-61.

LOHMANDER, H. 1939. Zur Kenntnis der Pseudoscorpionidenfauna Schwedens. *Entomologisk Tidskrift* 60: 279-323.

MAZZA, S. 1943. Comprobaciones de *Triatoma platensis*, *Eutriatoma oswaldoi*, *Pastrongylus seai y Psammolestes coreodes* en la provincia de Santiago del Estero, todas ellas sin infestación, y de *Eutriatoma sordida* con infestación por *S. cruzi*. Otros datos sobre infestación esquizotripanósica natural silvestre de *Triatoma infestans*. *La Prensa Médica Argentina* (Buenos Aires) 30(34): 15-83.

MUCHMORE, W. B. 1981. Cavernicolous species of *Larca, Archeolarca* and *Pseudogarypus* with notes on the genera (Pseudoscorpionida, Garypidae and Pseudogarypidae). *Journal of Arachnology* 9: 47-60.

MUCHMORE, W. B. 1990. Pseudoscorpionida (pp.502-527). *In*: DINDAL, D. L. (ed.). Soil Biology Guide. *John Wiley & Sons, Inc.*

MURTHY, V. A. & ANANTHAKRISHNAN, T. N. 1977. Indian Chelonethi. *Oriental Insects Monographs* 4: 1-210.

NELSON JR., S. O. 1971. Phoresy by pseudoscorpions. *Michigan Entomologist* 4: 95-96.

NORDBERG, S. 1936. Biologisch-ökologische Untersuchungen über die Vogelnidicolen. *Acta zoologica fennica* 21: 1-268.

OGAWA, G. M. 2008. Artrópodes em ninhos de *Columba livia* Gmelin, 1789 (Aves, Columbidae) em área urbana de Manaus, Amazonas, Brasil. *Entomologia Brasiliensis* 1(3): 69-72.

PECK, J. H. & ANDERSON, J. R. 1969. Arthropod predators of immature Diptera developing in poultry droppings in northern California Part I. Determination, seasonal abundance and natural cohabitation with prey. *Journal of Medical Entomology* 6: 163-167.

PETERSON, A. P. 2002. Zoonomen Nomenclatural data. Available from *http://www.zoonomen.net/avtax/frame.html* (accessed: June 2010)

PHILIPS, J. R. & DINDAL, D. L. 1990. Invertebrate populations in the nests of a screech owl (*Otus asio*) and an American kestrel (*Falco sparverius*) in central New York. *Entomological News* 101: 170-192.

PICKARD-CAMBRIDGE, O. 1892. Monograph on the British species of Chernetidea or false scorpions. *Proceedings of the Dorset Natural History and Antiquarian Field Club* 13: 195-231, plates A-C.

PIFANO, F. 1938. Anotaciones acerca del *Psammolestes arthuri* (Pinto, 1926) (Hemiptera, Heteroptera, Triatomidae), reduvideo hematófago encontrado en nidos de "cucarachero de monte" (probablemente Dendrocolaptidae) en un sector de los valles de Yaracuy. – Su importancia como posible vector en la naturaleza del *Schizotripanum cruzi*, Chagas 1909. *Gaceta Médica de Caracas* 45(16): 241-245.

PINTO, D. M., RIBEIRO, P. B., SILVEIRA JR., P. & BERNARDI, E. 2005. Flutuçao populacional de *Whitius piger* (Pseudoscorpionida) em granja avicola em Pelotas, RS, Brasil. *Archives of Veterinary Science* 10(2): 115-118.

PROPP, G. D. & MORGAN, P. B. 1985. Mortality of eggs and first-stage larvae of the house fly, *Musca domestica* L. (Diptera: Muscidae), in poultry manure. *Journal of the Kansas Entomological Society* 58: 442-447.

PUNG, O. J., CARLILE, L. D., WHITLOCK, J., VIVES, S. P., DURDEN, L. A. & SPADGENSKE, E. 2000. Survey and host fitness effects of red-cockaded woodpecker blood parasites and nest cavity arthropods. *Journal of Parasitology* 86(3): 506-510.

RANIUS, T. & WILANDER, P. 2000. Occurrence of *Larca lata* H. J. Hansen (Pseudoscorpionida: Garypidae) and *Allochernes wideri* C. L. Koch (Pseudoscorpionida: Chernetidae) in tree hollows in relation to habitat quality and density. *Journal of Insect Conservation* 4: 23-31.

REDIKORZEV, V. 1938. Les Pseudoscorpions de l'Indochine française recueillis par M. C. Dawidoff. *Mémoires du Muséum National d'Histoire Naturelle Paris* (N.S.) 10: 69-116.

REMSEN JR., J. V., CADENA, C. D., JARAMILLO, A., NORES, M. PACHECO, J. F., ROBBINS, M. B., SCHUKLENBERG, T. S., STILES, F. G., STOTZ, D. F. & ZIMMER, K. J. 2008. A classification of the bird species of South America. Version 11, January 2008. *American Ornithologists' Union, South American Classification Committee*. Available at *http://www.museum.lsu.edu/Remsen/SACCBaseline.html* (accessed June 2010).

RESSL, F. 1963. Können Vögel als passive Verbreiter von Pseudoscorpioniden betrachtet werden? *Die Vogelwelt* 84(4): 114-119.

RESSL, F. 1965. Über Verbreitung, Variabilität und Lebensweise einiger österreichischer After - skorpione. *Deutsche entomologische Zeitung* 12: 289-295.

RESSL, F. 1983. Die Pseudoskorpione Niederösterreichs mit besonderer Berücksichtigung des Bezirkes Scheibbs (pp. 174-202). *In*: RESSL. F. (ed.). Naturkunde des Bezirks Scheibbs. Die Tierwelt des Bezirkes Scheibbs, Band 2, Scheibbs. *Verlag R. u. F. Radinger*, 1-584.

RESSL, F. & BEIER, M. 1958. Zur Ökologie, Biologie und Phänologie der heimischen Pseudoskorpione. *Zoologische Jahrbücher, Systematik (Ökologie), Geographie und Biologie* 86: 1-26.

ROEWER, C. FR. 1937. Chelonethi oder Pseudoskorpione. *In*: BRONNS, H. G. (ed.): *Klassen und Ordnungen des Tierreichs, 5: Arthropoda. IV: Arachnoidea*, vol. 6(1-2): 1-320. Leipzig, *Akademische Verlagsgesellschaft*.

RYDER, J. P. & FREITAG, R. 1974. Densities of arthropod populations in nests of ring-billed gulls. *Canadian Entomologist* 106: 913-916.

SCHENKEL, E. 1928. Pseudoscorpionida (Afterskorpione). *In*: DAHL, F. (ed.). Die Tierwelt Deutschlands 8.Teil. Spinnentiere oder Arachnoidea III (pp. 52-72). Jena, *Verlag Gustav Fischer*.

SILVA, I. G. & LUSTOSA, E. S. 1993. Biologia de *Psammolestes tertius* Lent & Jurberg, 1965 (Hemiptera, Reduviidae). *Revista de Patologia Tropical* 22: 29-42.

SIMON, H. R. 1966. Wie gelangen Pseudoskorpione in Vogelnester? *Die Vogelwelt* 87(3): 80-83.

STAHLAVSKY, F. 2001. Stirci (Arachnida: Pseudoscorpiones) Prahy-Pseudoscorpions (Arachnida: Pseudoscorpiones) of Prague. *Klapalekiana* 37: 73-121.

THALER, K. 1979. Fragmenta Faunistica Tirolensia, IV (Arachnida: Acari: Caeculiidae; Pseudoscorpiones; Scorpiones; Opiliones; Aranei. Insecta: Dermaptera; Thysanoptera; Diptera Nematocera: Mycetophilidae, Psychodidae, Limoniidae und Tipulidae). *Veröffentlichungen des Museum Ferdinandeum* (Innsbruck) 59: 49-83.

THOMPSON, P. H. 1966. Arthropods from nests of the house sparrow. *Proceedings of the Entomological Society of Washington* 68(1): 44-48.

TOOREN, D. VAN DEN 2001. First record of the pseudoscorpion Larca lata in the Netherlands (Pseudoscorpiones: Garypoidea: Larcidae). *Nederlandse faunistische Mededelingen* 15: 33-39.

TOOREN, D. VAN DEN 2005. Naamlijst en determinatiesleutel tot de Pseudoschorpioenen van Nederland (Arachnida: Pseudoscorpiones). *Nederlandse faunistische Mededelingen* 23: 91-124.

TORRES, W. M. P. 2001. Fauna de artrópodes associada a ninhos de aves e mamíferos em uma floresta de terra firme na Amazônia Central, Brasil. *Dissertação de Mestrado em Ciências Biológicas (Entomologia), Universidade do Amazonas, Instituto Nacional de Pesquisas da Amazônia. Manaus, Brazil*, 126 pp.

TURIENZO, P. & DI IORIO, O. R. 2008. Insects found in birds's nests from Argentina: *Anumbius annumbi* (Vieillot, 1817) (Aves: Furnariidae). *Zootaxa* 1871: 1-55.

TURIENZO, P., DI IORIO, O. R. & MAHNERT, V. 2008. Resultados preliminares de pseudoescorpiones encontrados en nidos de aves de la Argentina (p. 129). *In*: II Congreso Latinoamericano de Aracnología & VI Encuentro de Aracnólogos del Cono Sur. Argentina, Salta, 30 de Noviembre – 4 de Diciembre. *Universidade de Salta*, 285 pp.

UCHIKAWA, K. 1970. Notes on the arthropod fauna of *Delichon urbica* nests in Nagano Prefecture. *Medical Entomology and Zoology* 21(1): 73-77.

WEYGOLDT, P. 1969. The biology of pseudoscorpions. *Harvard Books in Biology*, I-XIV+1-145.

WILLS, L. E., MULLENS, B. A. & MANDEVILLE, J. D. 1990. Effects of pesticides on filth fly predators (Coleoptera: Histeridae, Staphylinidae; Acarina: Macrochelidae, Uropodidae) in caged layer poultry manure. *Journal of entomological Entomology* 83(2): 452-457.

WOODROFFE, G. E. 1953. An ecological study of the insects and mites in the nests of certain birds in Britain. *Bulletin of Entomological Research* 44: 739-772

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# Four new earthworms of the *Amynthas aeruginosus* species group (Oligochaeta: Megascolecidae) from Nam Xam NBCA, Laos

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**Four new earthworms of the *Amynthas aeruginosus* species group (Oligochaeta: Megascolecidae) from Nam Xam NBCA, Laos. -** Earthworm specimens collected from the Nam Xam National Biodiversity Conservation Area, Laos belong to four new species of megascolecid earthworms: *Amynthas banlaoensis* sp. nov., *Amynthas khamlai* sp. nov., *Amynthas phadeangensis* sp. nov., and *Amynthas naphopensis* sp. nov. All four new species key to the *aeruginosus* group in Sims & Easton (1972), defined by having spermathecal pores in 7/8/9 and simple intestinal caeca. *Amynthas banlaoensis* sp. nov. has male pores superficial near lateral margins of XVIII in the $12^{th}$ setal lines, on short columnar 0.3-0.5 mm diameter porophore, and tubercular genital markings paired in VII or VIII. *Amynthas khamlai* sp. nov. has male pores on retractable, eversible round porophores near the lateral margins of the ventrum in XVIII, and circular genital markings in paired postsetal linear groups of two or three on trailing edges of VII and VIII. *Amynthas phadeangensis* sp. nov. has male pores on alate porophore swellings composed of concentric rings, with paired genital papillae medial to the male porophores and embedded in the concentric rings. It has paired postsetal genital markings in $8^{th}$ - $9^{th}$ setal lines of VIII and IX. *Amynthas naphopensis* sp. nov. has male pores in small invaginations partly covered by raised U-shaped flap concave medially, and lacks other genital markings.

**Keywords:** Earthworms - Megascolecidae - Oligochaeta - Laos - Nam Xam NBCA - taxonomy.

## INTRODUCTION

Like many countries in Southeast Asia, relatively little is known about the earthworms of Laos. A few parts of Laos have been studied with regard to the taxonomy of Megascolecidae (Thai & Samphon, 1988; 1989; 1990b; Hong *et al.*, 2008). Thai and Samphon also reported earthworm distribution data from several regions (Thai & Samphon, 1990a; 1991ab), for a total of 59 Megascolecidae in *Metaphire*, *Pithemera* and *Amynthas*. Thai & Samphon (1990a; 1991ab) placed all the Laotian worms of these genera in *Pheretima* Kinberg, 1867, but *Pheretima* had been revised by Sims & Easton (1972). Species with intestinal caeca originating in XXVII and lacking both copulatory pouches and nephridia on spermathecal ducts were placed in *Amynthas*.

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Taking into account this revision, *Amynthas* is the most diverse genus in the natural forests of northern Laos. Our recent collections are adding support to this statement.

During August 2004, collections were made in Nam Xam National Biodiversity Conservation Area (NBCA) in northern Laos, about 900 kilometres from Vientiane. Collections were made in the Important Bird Area (IBA), a higher-quality habitat zone located inside Nam Xam NBCA. The topography of the IBA is dominated by hills and low mountains, with a few peaks over 1,600 m elevation. The natural vegetation of the IBA comprises dry evergreen forest and mixed deciduous forest, with *Fokienia* forest at higher elevations, particularly in the west of the IBA, where most of the area is covered by evergreen forest on limestone. There are also some small areas of stunted, mossy upper montane forest at the highest elevations. Within Nam Xam NBCA, there are also significant areas of agricultural land and secondary re-growth following shifting cultivation, although these are mainly excluded from the IBA. The specimens were found in litter layers and soils in forests by digging and hand sorting.

In this paper, four species new to science are reported from Northern Laos. In Laos, *Amynthas* with two pairs of spermathecal pores come in two groups, those with the pores in 5/6 and 6/7, and those with the pores in 7/8 and 8/9. All four new species recorded here have pores in 7/8-8/9, corresponding to the *aeruginosus* group in Sims & Easton (1972).

Holotypes and paratypes are deposited in the Biology Department, Faculty of Science, National University of Laos, Vientiane (BDNUL). Paratypes are deposited in the Museum of Natural History of Geneva (MHNG), and the Korean Bioresources Collection, National Institute of Biological Resources (NIBR).

## DESCRIPTIONS

Family Megascolecidae Rosa, 1891
Genus ***Amynthas*** Kinberg, 1867

***Amynthas banlaoensis*** sp. nov. Figs 1A-B

Holotype: Clitellate (BDNUL 0009); Laos, Hoaphane province, Namxam NBCA, Xamtai district, South- Houa Heunh, BanLao village (20° 00.821' N, 104° 40.623' E), 448 m, mature forests 3 km from local village near cemetery, in soil and litter layers, 2 September 2004, K. Inkhavilay coll.

Paratypes: 1 semiclitellate (BDNUL 0013), 1 clitellate (MHNG INVE 68954), 1 clitellate (NIBRIV0000184280), same data as for holotype.

Other material: 3 semiclitellates, 5 aclitellates, same data as for holotype.

Etymology: The species is named for its type locality near the village of Ban Lao.

Diagnosis: Spermathecal pores two pairs in 7/8/9 at $11^{th}$ setal lines; male pores superficial near lateral margins of ventrum in XVIII at $12^{th}$ setal lines, on short columnar 0.3-0.5 mm round porophore, base of porophores in shallow parietal invagination.

Description: Dimensions 83-150 mm by 6.4-6.5 mm at segment X, 5.0-6.5 mm at segment XXX, 5.0-6.4 mm at clitellum; body cylindrical, segments 85-113. Setae regularly distributed around segmental equators, numbering 40-47at VII, 48-52 at XX,

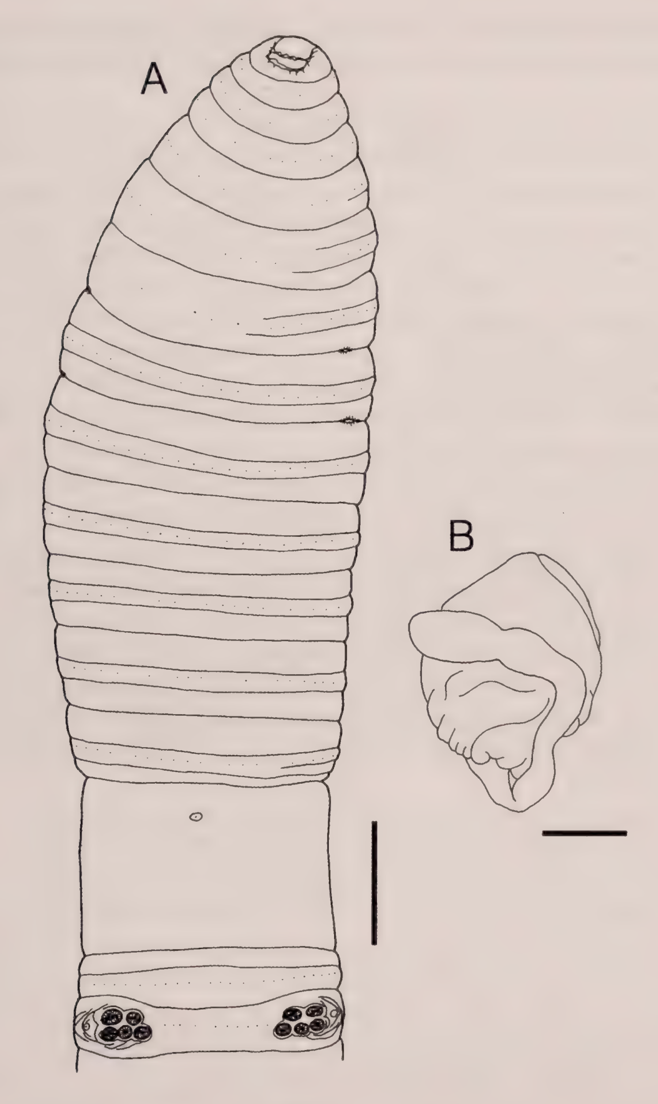



FIG. 1

*Amynthas banlaoensis* sp. nov. (A) Ventral view. (B) Spermathecae and diverticulum. Scale bars = 2.5 mm (A), 1 mm (B).

5-12 between male pores, setal formula AA:AB:ZZ:YZ= 4.5:3:4:3 at XIII. Female pore single in XIV, on 0.2-0.3 mm oval. Prostomium epilobic with tongue open. Brown dorsal pigment, clitellum coffee color, formalin preservation. First dorsal pore at 12/13. Clitellum annular XIV-XVI; setae invisible externally.

Male pores superficial near lateral margins of ventrum in XVIII at 12$^{th}$ setal lines, on short columnar 0.3-0.5 mm round porophores, base of porophores in shallow parietal invagination. Between male pores two groups of papillae, each containing 2-4 circular presetal genital papillae, 1-3 postsetal genital papillae. Tubercular genital

markings paired VII or VIII, some in the middle of ventrum and some at lateral margins. Spermathecal pores two pairs in 7/8, 8/9 at $11^{th}$ setal lines at lateral margins of ventrum.

Septa 5/6-7/8 thick, 8/9-9/10 absent, 10/11-13/14 thick. Gizzard in VIII-X. Intestine begins in XV, lymph glands from XXV. Typhlosole origin in XXV, full size XXVIII, ¼ lumen diameter. Intestinal caeca simple big finger-shaped sac with 5-6 short pockets on ventral margins, originating at XXVII, and extending anteriorly about to XXIV. Hearts in X-XIII. Male sexual system holandric, testes and funnels in ventrally joined sacs in X, XI. Seminal vesicles large pairs in X-XII, well developed, with ovate dorsal lobes in shallow clefts. Prostates well developed XVIII extending to XVII-XXII, each containing about 5-6 lobes partly attached to body wall. Crowded small stalked mushroom-shaped genital papillae glands in XVIII.

Ovaries in XIII. Paired spermathecae in VII, VIII; VIII bigger than VII, each ampulla is large, round but flattened by gizzard; short, stout muscular duct, shorter than ampulla, diverticulum chamber sausage-shaped, stalk short, no nephridia on spermathecae ducts. Short-stalked genital marking glands leaf-shaped in VII, VIII.

REMARKS: *Amynthas banlaoensis* sp. nov. keys to the *aeruginosus* group in Sims & Easton (1972). In this group, the following Laos species are recorded: *Amynthas choanus* (Thai & Samphon, 1988), *Amynthas otoformes* (Thai & Samphon, 1989), and *Amynthas uanus* (Thai & Samphon, 1990). *Amynthas otoformes* and *Amynthas uanus* have male fields very unlike the other *aeruginosus*-group species in Laos. *Amynthas choanus* has only one circular genital papilla in the male pore region, and is of smaller size (52 mm by 2 mm) than *Amynthas banlaoensis* sp. nov. (83-150 mm by 6.4-6.5 mm).

The new species is similar to *A. omeimontis* (Chen, 1946), with respect to the length, segments, setae, first dorsal pore, and type of caeca. It differs from *A. omeimontis* which has two groups of genital papillae, three to seven genital papillae surrounding the depression of male pore region, and another group of two to seven on antero-medial side of the depression in front of setal circle, but *Amynthas banlaoensis* sp. nov. has two to four circular genital papillae and one to three postsetal papillae between the male pores. In *A. omeimontis* there are about 40 to 50 small genital markings closely arranged in rows covering the setal zone of the ventral side of $11^{th}$ segment and anteriorly to intersegmental furrow 10/11, but the new species has no genital marking outside the spermathecal pore region. The spermathecae of *Amynthas banlaoensis* sp. nov. have ducts shorter than the ampullae, but *A. omeimontis* has ducts longer than ampullae.

***Amynthas khamlai*** sp. nov. Figs 2A-B

HOLOTYPE: Clitellate (BDNUL 0010), Laos, Hoaphane province, Namxam NBCA, Xamtai district, Hoaue Du mountain (20° 01.040' N, 104° 39.205' E), 384 m, thin layer soil with some leaf litter, secondary forest with bamboos and trees, 5 km from local village, in soil and litter layers, 12 September 2004, K. Inkhavilay coll.

PARATYPES: 1 semiclitellate (BDNUL 0014), 1 semiclitellate (MHNG INVE 68955), 1 semiclitellate (NIBRIV0000184281), same data as for holotype.

OTHER MATERIAL: 1 aclitellate, same data as for holotype.

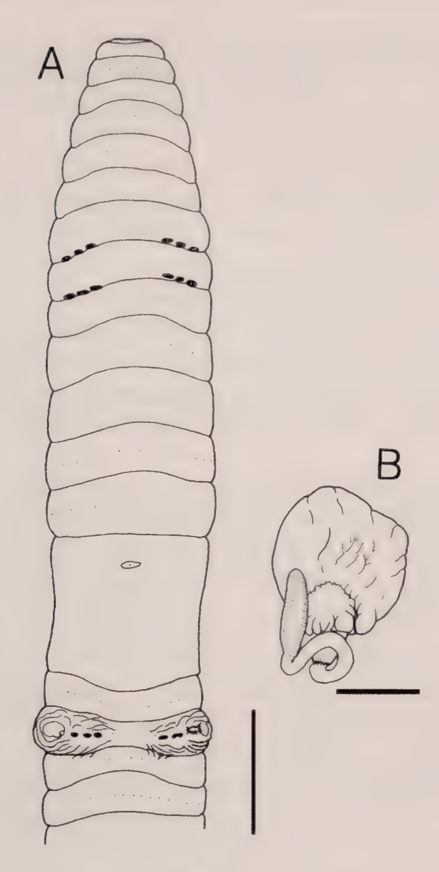



FIG. 2

*Amynthas khamlai* sp. nov. (A) Ventral view. (B) Spermathecae and diverticulum. Scale bars = 3 mm (A), 4 mm (B).

ETYMOLOGY: The species is named for the collector, Khamla Inkhavilay.

DIAGNOSIS: Spermathecal pores paired in 7/8/9 between 7th and 8th setal lines; male pores on retractable, eversible round porophores in XVIII at 11th setal lines.

DESCRIPTION: Dimensions 65-81 mm by 4.5-4.6 mm at segment X, 4.4-4.5 mm at segment XXX, 4.1-4.5 mm at clitellum; body depressed, segments 110-114. Setae regularly distributed around segmental equators, numbering 38-40 at VII, 48-50 at XX, 7-13 between male pores, setal formula AA:AB:ZZ:YZ= 3:2.5:3:2.5 at XIII. Female pore single in XIV, on 0.2-0.3 mm oval porophore. Prostomium epilobic with tongue open. Brown dorsal pigment, yellowish ventrally, clitellum coffee color, formalin preservation. First dorsal pores at 11/12. Clitellum annular XIV-XVI; setae invisible externally.

Male pores on retractable, eversible round porophores near lateral margins of ventrum in XVIII at 11th setal lines, surrounded by thickened half-circle connected to elevated zone bearing genital papillae, 4.0-4.5 mm between male pores. Between male pores paired linear groups of 2-4 postsetal round genital papillae; lateral-most papillae

on retractable porophore with male pore. Spermathecal pores paired in 7/8-8/9 between 7th and 8th setal lines, lateral to genital markings, on small bumps at trailing edges of VII, VIII. Genital markings paired linear groups of 2-3 postsetal circles in VII, VIII on posterior edges; sometimes in VI.

Septa 5/6-7/8 thick; 8/9-9/10 absent; 10/11-12/13 thin. Gizzard globular and large in VIII-X. Intestine begins in XVI, lymph glands found from XVIII. Typhlosolar fold < 1/3 lumen from XXVII. Intestinal caeca simple, originating in XXVIII, extending anteriorly about to XXIV, finger-shaped with serrate ventral margin. Hearts X-XIII. Male sexual system holandric, testes and funnels in ventrally joined sacs in X-XI. Seminal vesicles XI-XII with small dorsal lobe set deeply in a dorsal cleft. Prostates in XVIII between XVI-XXI divided into many short, deeply divided lobes, duct muscular, S-curved. Genital papillae glands with long slender stalks and small glandular heads in XVIII, numbers of glands corresponding to numbers of genital papillae.

Ovaries in XIII. Paired spermathecae preseptal in VIII, postseptal in IX, broad lenticular cordate ampullae, diverticulum slender stalk as long as ampulla with chili-shaped chamber, no nephridia on spermathecal ducts. Genital marking glands same structure as in XVIII, numbers of glands corresponding to numbers of genital markings in VII, VIII close to spermathecal ducts.

REMARKS: This species also keys to the *aeruginosus* group in Sims & Easton (1972), within which *Amynthas khamlai* sp. nov. is distinguished by the patterns of genital papillae, and genital markings. *Amynthas khamlai* sp. nov. is similar to *Amynthas phadeangensis* sp. nov., with respect to body length, spermathecal pores, and presence of genital markings, but the details are different. *Amynthas khamlai* sp. nov. has genital markings in paired linear groups of 2-3 postsetal in VII, VIII on trailing edges of those segments, but *Amynthas phadeangensis* sp. nov. has paired postsetal genital markings in VIII, IX closer to the segmental equators. *Amynthas khamlai* sp. nov. has far fewer setae between the male pores (7-13 vs. 39-42). The spermathecal pores in *Amynthas khamlai* sp. nov. are between the 7th and 8th setal lines, but those of *Amynthas phadeangensis* sp. nov. are in the 13th setal lines. *Amynthas khamlai* sp. nov. has the intestinal origin in XVI as opposed to XV for *Amynthas phadeangensis* sp. nov. This new species is similar to *A. robustus* (Perrier, 1872), and *A. arrobustus* (Thai, 1984), but it differs from them in the characters of the male pore region. The genital papilla of *A. arrobustus* is single and presetal in XVIII, but *Amynthas khamlai* sp. nov. has 2-4 postsetal papillae. The new species is similar to *A. robustus*, but is separated easily by the genital markings of spermathecal pores. Genital markings of *A. robustus* are small, only one intersetal interval wide and are present inside the spermathecal porophore, and in one or more of the following locations within VII and/or VIII: just in front of the spermathecal pores, just behind the spermathecal pores, or median to the pores and presetal (Gates, 1972).

***Amynthas phadeangensis* sp. nov.** Figs 3A-B

HOLOTYPE: Clitellate (BDNUL 0011); Laos, Hoaphane province, Namxam NBCA, Xamtai district, Pha Deang mountain, Ban Lao village (20° 00.727' N, 104° 39.894' E), 681 m, secondary forest with small trees and some bamboos 10 km from village, in soil and litter layers, 3 September 2004, K. Inkhavilay coll.

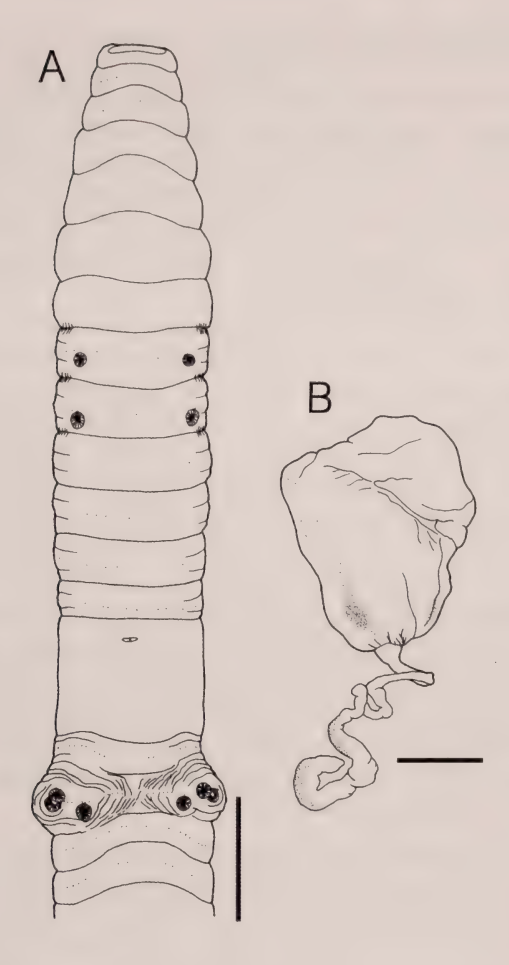



FIG. 3

*Amynthas phadeangensis* sp. nov. (A) Ventral view. (B) Spermathecae and diverticulum. Scale bars = 4 mm (A), 2 mm (B).

PARATYPE: 1 semiclitellate (BDNUL 0015), same data as for holotype.

OTHER MATERIAL: 1 aclitellate, same data as for holotype.

ETYMOLOGY: The species is named for its type locality, Pha Deang mountain.

DIAGNOSIS: Spermathecal pores two pairs in 7/8/9 at lateral margins of ventrum 13th setal line; male porophores alate swellings composed of concentric rings; pores within small central porophore.

DESCRIPTION: Dimensions 50-110 mm by 4.0-5.0 mm at segment X, 4.4-4.7 mm at segment XXX, 4.0-6.0 mm at clitellum; body cylindrical throughout, segments 59-102. Setae evenly distributed around segmental equators, numbering 45-47 at VII, 60-65 at XX, 39-42 between male pore, setal formula AA:AB:ZZ:YZ= 3:3:4:3 at XIII. Female pore single in XIV, on 0.1-0.3 mm oval. Prostomium epilobic with tongue

open. Light brownish dorsal pigment, clitellum coffee color, formalin preservation. First dorsal pore at 12/13. Clitellum annular XIV-XVI; setae invisible externally.

Male pores near lateral margins of ventrum in XVIII, on alate swellings composed of concentric rings; pores within small central porophore. Paired genital papillae presetal, medial to male porophore; additional pair of genital papillae postsetal embedded in outer concentric rings, pore 0.2-0.3 mm in diameter. Spermathecal pores two pairs in 7/8, 8/9 at lateral margins of ventrum in 13$^{th}$ setal lines. Paired postsetal genital markings in 8$^{th}$ - 9$^{th}$ setal line VIII, IX; paired genital markings VIII nearly in furrow 8/9, median to spermathecal pores.

Septa 5/6-7/8 muscular, 8/9-9/10 absent, 10/11-12/13 slightly muscular. Gizzard in VIII-X. Intestine begins in XV, lymph glands not found. Typhlosole simple fold about 1/4 lumen diameter found from XXVII. Intestinal caeca simple, originating in XXVII, extending interiorly about to XXII, finger-shaped with 8-10 pockets on ventral margin. Intestine deeply pouched 21-25, with small typhlosole ridge ending at 25/26, no other blood vessel ridges in this area. Esophageal hearts X-XIII. Male sexual system holandric, testes and funnels in ventrally joined sacs in X-XI. Seminal vesicle two large pairs in XI-XII, with small round dorsal lobes. Prostates in XVIII large between XVI-XXIII, each containing about 4-6 main lobes, thick muscular duct. Genital papillae glands sessile, very large in XVIII, two pairs; transverse muscle bands anterior to prostatic duct, covering anterior pair of genital papillae glands.

Ovaries in XIII. Paired spermathecae in VIII and IX, each ampulla large ovate to sagittate sacs, duct short and muscular without nephridia, some small black pigment dots on ampulla surface, diverticulum with muscular stalk, long kinked chamber, diverticulum shorter than ampulla. Three pairs large genital marking glands VIII-IX near spermathecae, very short stalked or sessile.

REMARKS: The species shares some internal characteristics of the prostates, seminal vesicles, septa, pigment, and esophageal hearts with *Amynthas khamlai* sp. nov. Distinctions were detailed above under *Amynthas khamlai* sp. nov. *Amynthas phadeangensis* sp. nov. has an unusual intestine, which is deeply pouched in XXI-XXV with a small typhlosolar ridge ending at 25/26. The present species appears to be closely related to *A. longisiphonus* (Qiu, 1988) from Guizhou, China with two spermathecal pores in 7/8 and 8/9, but it is separated easily by the shape of the male pore region and genital markings. *Amynthas longisiphonus* has 5-8 pairs of papillae on the ventral side in XVIII-XXII or XXV, but *Amynthas phadeangensis* sp. nov. has paired presetal papillae, and paired postsetal papillae in XVIII. The new species is different from *A. robustus* and *A. arrobustus* in respect to the shape of the male pore region and genital papillae, *Amynthas robustus* usually has two papillae just median to each male porophore. The male porophore is on a thick disk, and the spermathecal pores are near mid-lateral.

***Amynthas naphopensis* sp. nov.** Figs 4A-B

HOLOTYPE: Clitellate (BDNUL 0012);Lao, Hoaphane province, Xamtai district, Namxam NBCA, Naphop mountain NBCA. (20° 01.588' N, 104° 39.422' E), 414 m, good forest with thick litter layer, 10 km from village near a stream, in soil and litter layers, 4 September 2004, K. Inkhavilay coll.

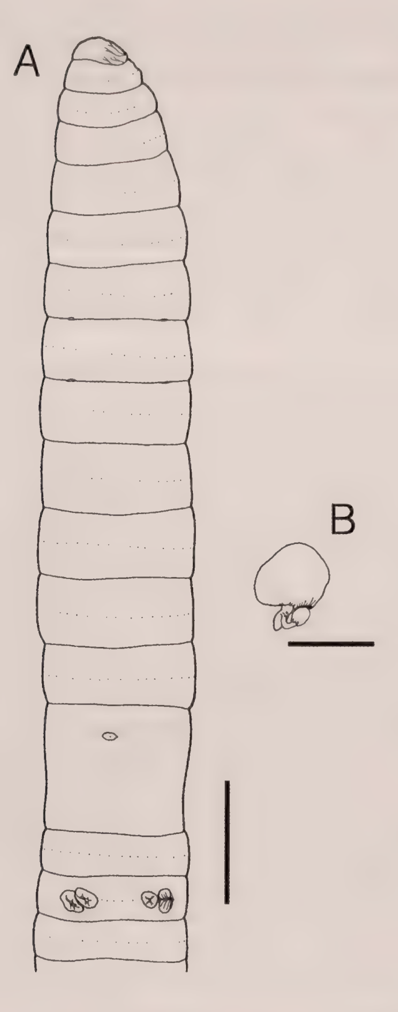



FIG. 4
*Amynthas naphopensis* sp. nov. (A) Ventral view. (B) Spermathecae and diverticulum. Scale bars = 3 mm (A), 2 mm (B).

PARATYPES: 1 semiclitellate (BDNUL 0016), 1 clitellate (MHNG INVE 68956), 1 clitellate (NIBRIV0000184282), same data as for holotype.

OTHER MATERIAL: 10 clitellates, same data as for holotype; 60 clitellates, Namxam NBCA, Pha tolk, (20° 00.552' N, 104° 40.369' E), 470 m, soil and litter layers, 6 September 2004, K. Inkhavilay coll.

ETYMOLOGY: The species is named for its type locality, Naphop mountain.

DIAGNOSIS: Spermathecal pores two pairs in 7/8/9 at 7$^{th}$ setal lines; male pores XVIII at 6$^{th}$ setal lines in small invaginations partly covered by raised U-shaped flap concave medially.

DESCRIPTION: Dimensions 58-67 mm by 3.5-3.7 mm at segment X, 3.4-3.7 mm at segment XXX, 3.5-3.6 mm at clitellum; body cylindrical, segments 49-66. Setae regularly distributed around segmental equators, numbering 38-39 at VII, 40-42 at XX, 4-10 between male pores, setal formula AA:AB:ZZ:YZ= 2:2:3:2 at XIII. Female pore conspicuous single in XIV, on 0.2-0.3 mm oval. Prostomium epilobic with tongue open. Dark brown dorsal pigment, lighter on dorsal setal rings, lighter brown ventrally, VII–IX unpigmented between spermathecal pores. Clitellum coffee color, formalin preservation. First dorsal pore at 5/6. Clitellum annular XIV-XVI; setae invisible externally. On post-clitellate segments, ventral-most section spanning DD in XX to FF by XL, elevated within segments, furrows thus deepened, ventrum ladder-like in appearance.

Male pores XVIII at 6$^{th}$ setal lines in small invaginations partly covered by raised U-shaped flap concave medially, enclosing two oval genital papillae, 2.2-2.5 mm between male pores. Spermathecal pores two large pairs in 7/8, 8/9 at 7$^{th}$ setal lines conspicuous near the lateral margins of ventrum, about 0.7-0.9 mm between spermathecal pores. Paired equatorial genital papillae, median to male pores on XVIII, circular or oval-shaped, but mostly circular; size variable. Genital markings lacking.

Septa 5/6/7/8 thick, 8/9-9/10 absent, 10/11-12/13 very thin. Gizzard in VIII-X. Intestine begins in XV, lymph glands not found. Typhlosole low fold from XXVII. Intestinal caeca simple, originating in XXVIII, extending anteriorly about to XXIV, finger-shaped with smooth margins or only segmental indentations. Hearts X-XIII. Male sexual system holandric, testes and funnels in ventral paired sacs in X-XI; sacs of a side united. Seminal vesicles two pairs large, without dorsal lobes in XI-XII, vesicle of XI extends into X. Prostates in XVIII between XVII-XIX each containing 3 main lobes, many small deeply divided secondary lobes, muscular ducts coiled in 540° spiral, spiraling proximal to distal counter-clockwise on right side and clockwise on left side; short non-muscular section from gland to spiral twisted opposite. Genital papillae glands and copulatory pouches not found.

Ovaries in XIII. Paired spermathecae in VII, VIII each ampulla large ovate to rounded angular, muscular duct very short, a little bit longer than diverticulum, short diverticulum egg-shaped chamber, no nephridia on the spermathecal ducts. Genital marking glands not found.

REMARKS: The present species keys to the *aeruginosus* group by the two spermathecal pores in 7/8-8/9. *Amynthas naphopensis* sp. nov. has spermathecal pores in 7/8 and 8/9, but spermathecae are in VII, VIII, so these are unusual preseptal spermathecae. This species has distinctive prostatic ducts coiled in 540° spirals, the spiraling directions opposite on the two sides of the body. Finally, the elevated ventral setal zones of post clitellar segments are also distinctive. Thus *Amynthas naphopensis* sp. nov. is easily distinguished from the other members of the species group.

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## REFERENCES

CHEN, Y. 1931. On the terrestrial Oligochaeta from Szechuan. *The Science Society of China, Nanking, China* 7: 117-171.

CHEN, Y. 1946. On the terrestrial Oligochaeta from Szechwan III. *Journal of the West China Border Research Society* 16: 83-141.

HONG, Y., JAMES, S. W. & INKHAVILAY, K. 2008. A new species of the genus *Pithemera* (Oligochaeta: Megascolecidae) from Namat NBCA, Laos. *The Korean Journal of Systematic Zoology* 24: 161-164.

GATES, G. E. 1972. Burmese earthworms, an introduction to the systematics and biology of megadrile oligochaetes with special reference to Southeast Asia. *Transaction of the American Philosophical Society*, N.S 62: 1–326.

QIU, J. 1988. Two new species of the genus *Pheretima* from Guizhou (Oligochaeta: Megascolecidae). *Sichuan Journal of Zoology* 7: 1-4. [in Chinese]

SIMS, R. W. & EASTON, E. G. 1972. A numerical revision of the earthworm genus *Pheretim*a auct. (Megascolecidae: Oligochaeta) with the recognition of new genera and an appendix on the earthworms collected by the Royal Society North Borneo Expedition. *The Biological Journal of the Linnean Society, London* 4: 169-268.

THAI, T. B. 1984. New species of the genus *Pheretima* in Vietnam. *Zoological Journal* 63: 1317-1328. [in Russian]

THAI, T. B. & SAMPHON, K. 1988. New species and subspecies of earthworms from Laos. *Scientific information of Hanoi University of Education* 3-25. [in Vietnamese]

THAI, T. B. & SAMPHON, K. 1989. Initial remarks on the fauna of earthworm in Laos (from Muong Phuon to Bualave plateaux). *Scientific information of Hanoi University of Education* 61-74. [in Vietnamese]

THAI, T. B. & SAMPHON, K. 1990a. The fauna of earthworms of Luongphabang Province (Laos). *Scientific information of Hanoi University of Education* 3-13. [in Vietnamese]

THAI, T. B. & SAMPHON, K. 1990b. New species of earthworms from Luongphabang, Laos. *Journal of Biology, National Centre for Natural Science and Technology of Vietnam* 12: 11-14. [in Vietnamese]

THAI, T. B. & SAMPHON, K. 1991a. A list of discovered species of earthworms fron Laos. *Scientific information of Hanoi University of Education* 86-89. [in Vietnamese]

THAI, T. B. & SAMPHON, K. 1991b. Earthworms of some regions skirting the middle part of Mekong River in Laos (from Vienian to Pacse). *Journal of Biology, National Centre for Natural Science and Technology of Vietnam* 13: 1-10. [in Vietnamese]

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# A new genus of Sensitibillini from Brazilian caves (Psocodea: 'Psocoptera': Prionoglarididae)

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**A new genus of Sensitibillini from Brazilian caves (Psocodea: 'Psocoptera': Prionoglarididae). -** The genus *Neotrogla* Lienhard gen. n. is described for three new cave-dwelling species from Brazil: *Neotrogla brasiliensis* Lienhard sp. n. (from Minas Gerais State), *N. aurora* Lienhard sp. n. (from Tocantins State) and *N. truncata* Lienhard sp. n. (from Bahia State). These species are the first Neotropical representatives of the sub - family Speleketorinae and the first New World representatives of the tribe Sensitibillini, previously known only from southern Africa. This distributional pattern of Sensitibillini is tentatively interpreted as due to Western Gondwanan vicariance. In the females of *Neotrogla* a complex of accessory structures to the spermathecal duct is described and denoted by the new term "gynosome". A hypothesis of functional complementarity, during copulation, between the "penis-like" gynosome and the strongly reduced male phallosome of *Neotrogla* is presented.

**Keywords:** New species - Brazil - cave fauna - gynosome - phallosome - copulation - Western Gondwanan vicariance - living fossils.

## INTRODUCTION

The current knowledge of the Brazilian 'Psocoptera' (i.e. non-parasitic Psocodea, see below) fauna has been summarized by García Aldrete & Mockford (2009). It is clear that this picture is incomplete, and that the Neotropical fauna, especially of subterranean biotopes, is poorly known. Recent studies of Brazilian caves have yielded numerous as yet undescribed species, and suggest that an unexpected diversity of Psocoptera awaits discovery. This paper reports the results of a study of the family Prionoglarididae, which has not previously been recorded from Brazil.

Within the order Psocodea (*sensu* Yoshizawa & Johnson, 2006) the 'Psocoptera' family Prionoglarididae belongs to the basal suborder Trogiomorpha and has recently been placed in an infraorder of its own, the Prionoglaridetae (see Yoshizawa *et al.*, 2006). The family has been subdivided into two subfamilies by Lienhard (2004), Prionoglaridinae and Speleketorinae. The nominate subfamily contains three genera, the Palaearctic *Prionoglaris* Enderlein (3 species; see Lienhard & Smithers, 2002), the Oriental *Siamoglaris* Lienhard (monotypic; see Lienhard, 2004) and the Neotropical

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*Speleopsocus* Lienhard (monotypic; see Lienhard *et al.*, 2010). The subfamily Speleketorinae has been subdivided into two tribes by Lienhard (2007), the Speleketorini, containing the Nearctic genus *Speleketor* Gurney (3 species; see Lienhard & Smithers, 2002), and the Sensitibillini, containing the Aethiopian genera *Sensitibilla* Lienhard (4 species; see Lienhard, 2007 and Lienhard *et al.*, 2010) and *Afrotrogla* Lienhard (3 species; see Lienhard, 2007). Most of the previously known prionoglaridids live in caves or similar habitats.

In the following we describe the first Neotropical representatives of the subfamily Speleketorinae and of the tribe Sensitibillini, three new species from Brazilian caves which are assigned to a new genus closely related to *Afrotrogla* known from southern Africa (South Africa and Namibia). The biogeographical implications of the distributional pattern of Sensitibillini are briefly discussed. In the female of the new genus, a very particular "penis-like" structure of the spermapore region, associated to the spermathecal duct, is described and a hypothesis of its function during copulation is presented. The new term "gynosome" is introduced for this structure in analogy to the term phallosome, normally used for the male copulatory organ of Psocoptera.

## MATERIAL AND METHODS

The collection of specimens in most caves was performed by manual capture. In addition, pitfalls containing formalin (5%) and liver baits were used in the caves Caboclo, Ossos and Janelão (Minas Gerais State). Dissection and slide-mounting followed the methods described by Lienhard (1998). The material examined is deposited in the following institutions: Universidade Federal de Lavras, Departamento de Biologia (Coleção de Invertebrados Subterrâneos), Lavras, Brazil (ISLA); Muséum d'histoire naturelle, Geneva, Switzerland (MHNG); Systematic Entomology, Hokkaido University, Sapporo, Japan (SEHU).

The following abbreviations are used in the descriptions: Ant = antenna (length); BL = body length (in alcohol); F = hindfemur (length); f1, f2, etc. = antennal flagellomeres (length); FW = forewing (length); HW = hindwing (length); IO/D = shortest distance between compound eyes divided by anteroposterior diameter of compound eye in dorsal view of head; P1-P4 = articles of maxillary palp; T = hindtibia (length); t1, t2, t3 = tarsomeres of hindtarsus (length, measured from condyle to condyle). Abbreviations of wing veins and cells are used according to Yoshizawa (2005). Details of genital morphology are explained in Fig. 10.

Bibliographical references of original taxa descriptions not given in this paper can be found in Lienhard & Smithers (2002) and Lienhard (2007).

## DESCRIPTIONS

### *Neotrogla* Lienhard gen. n.

Diagnosis: Belonging to the subfamily Speleketorinae (as defined by Lienhard, 2004) and to the tribe Sensitibillini (as defined by Lienhard, 2007), but different from the previously known genera of this tribe due to the presence, in adults and nymphs, of a longitudinal row of articulated spines on anterior face of forefemur (Fig. 3a) and of a tarsal trichobothrium not only on second article of hindtarsus but also on second

article of midtarsus (Fig. 4). Habitus similar to *Sensitibilla* (see Lienhard *et al.*, 2010: fig. 4) and *Afrotrogla*. General morphology of adult and nymph as described for *Sensitibilla* (see Lienhard, 2000, 2007), with the following differences also present in the genus *Afrotrogla*. Hindwing (Fig. 1b) with M 2-branched. Third article of hindtarsus in females preapically with a dorsal pair of long curved hairs; the corresponding hairs much shorter in males and on foretarsus and midtarsus of both sexes. Female terminalia: ventral half of female paraproct with numerous short setae (Fig. 2c), lacking the circular field of long dense pilosity present in *Sensitibilla*; posterior lobe of subgenital plate at least slightly sclerotized and clearly visible medially between the pair of elongate ovipositor valvulae (external gonapophyses) (Figs 1c, 5, 8d); spermathecal wall with some sclerotized wrinkles near origin of spermathecal duct (Figs 2e, 7c). Male terminalia: paraproct (Fig. 3b) with a prominent ventral lobe (sometimes inconspicuous); phallosome with a narrow sclerite forming a simple aedeagal arch (Fig. 3e).

Differing from *Afrotrogla* not only by the above mentioned presence of a row of spines on forefemur and of a trichobothrium on second article of midtarsus but also by the following characters: spermapore region differentiated as an elongate "penis-like" gynosome (Fig. 2d, f; see also General Discussion), lacking the pair of lateral sclerotized struts present in *Afrotrogla* (see Fig. 10a:12' and Lienhard, 2007: figs 4g, 6d) [the gynosome of *Neotrogla* (see Fig. 10b, c) is a longitudinal structure composed of a weakly sclerotized posterior sac bearing the spermapore at its tip and enclosing the distal part of the spermathecal duct, a blister-like median part consisting of denticulate membranous structures and an anterior sclerotized rod]; internal lobe of basal part of external gonapophysis weakly differentiated (Figs 1c, 10b:4'), this gonapophysis not wider in middle than its foliaceous distal process (contrary to *Afrotrogla*, Fig. 10a:4'); posterior lobe of subgenital plate (Figs 1c, 10b:2) basally narrowed (broad in *Afrotrogla*, Fig. 10a:2); dorsally of external gonapophyses two pairs of apically rounded membranous and glabrous lobes present (ventral and dorsal gonapophyses? – absent in *Afrotrogla*), more or less covered ventrally by the basal parts of the external gonapophyses and by the posterior lobe of the subgenital plate (Figs 1c, 8d); aedeagal arch of the phallosome (Figs 3e, 9b) about half as long as the distance between its apex and the posterior end of the ejaculatory duct (= de) (much longer in *Afrotrogla*, reaching the ejaculatory duct; see Lienhard, 2007: fig. 7c) (Note: The width of the aedeagal arch depends largely on the degree of squashing of slide-mounted terminalia); endophallus (Figs 3e, 9b) medially with a longitudinal area densely covered by sclerotized papillae between the aedeagal arch and the ejaculatory duct (endophallic papillae absent in *Afrotrogla*); membrane of forewing with some brown colouration along several veins in basal half (Fig. 1a) (entirely hyaline in *Afrotrogla*); apical half of P4 (Fig. 7d) with 2 thin-walled preapical conical sensilla (5 such sensilla in *Afrotrogla*); tufts of long backwards-directed sternal setae near midline at about basal one third of abdomen absent in both sexes (present in females of *Afrotrogla*; see Lienhard, 2007: figs 4c, 6g).

Type species: *Neotrogla brasiliensis* Lienhard sp. n.

Other species: *N. aurora* Lienhard sp. n. and *N. truncata* Lienhard sp. n.

ETYMOLOGY: The name of the genus is feminine in gender and refers to its Neotropical distribution (Neo-) and its close relationship to the African genus *Afrotrogla* (-trogla).

DISCUSSION: See General Discussion.

***Neotrogla brasiliensis*** Lienhard sp. n. Figs 1-3 and 10b, c

HOLOTYPE: ISLA, ♀, Brazil (Minas Gerais), Januária, cave "Gruta Caboclo", 27.iii.2003, leg. R. L. Ferreira.

PARATYPES: 3♂, 2♀ ISLA; 2♂ SEHU (for DNA extraction); 1♂, 1♀ MHNG; same data as for holotype. – 1 ♀ MHNG, same data as for holotype, but 22.iii.2003. – 1 ♂ MHNG, Brazil (Minas Gerais), Januária/Itacarambi, cave "Gruta Janelão", vii.2003, leg R. L. Ferreira. – 1♂, 2 nymphs ISLA; 2 nymphs MHNG; Brazil (Minas Gerais), Januária, cave "Gruta Ossos", vii.2003, leg. R. L. Ferreira.

DESCRIPTION

*Male and female*: See generic diagnosis, with the following additions. Head, thorax and appendages in general light to medium brown. Wings transparent (pterostigma very slightly opaque), veins brown, some brown pigmentation on membrane in basal half, as shown in Fig. 1a, b. In forewing fused portion of Rs and M longer than basal portion of Rs (Fig. 1a). Head with several small patches of brown hypodermal pigment (similar to Fig. 7a), shape and extension of these patches somewhat variable; compound eyes black, relatively small in both sexes (see Measurements: IO/D); vertical suture brown, frontal suture not visible. Ocelli well-developed, arranged in a slightly flattened triangle (see Fig. 7a). Vertex on each side behind lateral ocellus with a slightly concave area. Antennae damaged in all specimens examined (the best-preserved antenna examined is broken within f6), flagellomeres finely annulate. Maxillary palp long and slender (see Lienhard, 2007: fig. 3e), P2 with a well-differentiated subbasal sensory spur, P4 with two subapical conical sensilla, the more distal one slender and sometimes difficult to observe (see Fig. 7d). Trichobothria-bearing tarsomeres medially slightly thickened, but this thickening less distinct in midtarsus than in hindtarsus. Abdomen yellowish white, dorsally and laterally with longitudinal rows of reddish brown patches of hypodermal pigment (similar to Fig. 7b), often some patches partly fused to form irregular segmental transversal bands; terminalia yellowish brown.

Female terminalia: Epiproct and paraproct simple (Fig. 2c); paraproct with a sense cushion bearing 6 simple trichobothria (lacking basal rosettes) and usually also one normal seta in middle; posterior margin of sense cushion with several short sclerotized wrinkles. Subgenital plate (Fig. 1c) subdivided into a broad membranous anterior part, bearing a posteriorly opened curved sclerotized area of somewhat variable shape (Fig. 10b:1), and a slightly sclerotized elongate posterior lobe (Fig. 10b:2). The latter basally bearing a bifurcate sclerite (Fig. 10b:3) covered ventrally by a membranous transversal fold formed by the hindmargin of the anterior part of the subgenital plate. Posterior lobe apically rounded and densely covered by fine micro-trichia, with a pilose subapical area on each side and two weakly differentiated small lobes subapically on lateral margin; medially between these lobes a somewhat crescent-like sclerotization and anteriorly to it a smooth and less sclerotized oval area. A pair of long foliaceous external gonapophyses (ovipositor valvulae) present, each of

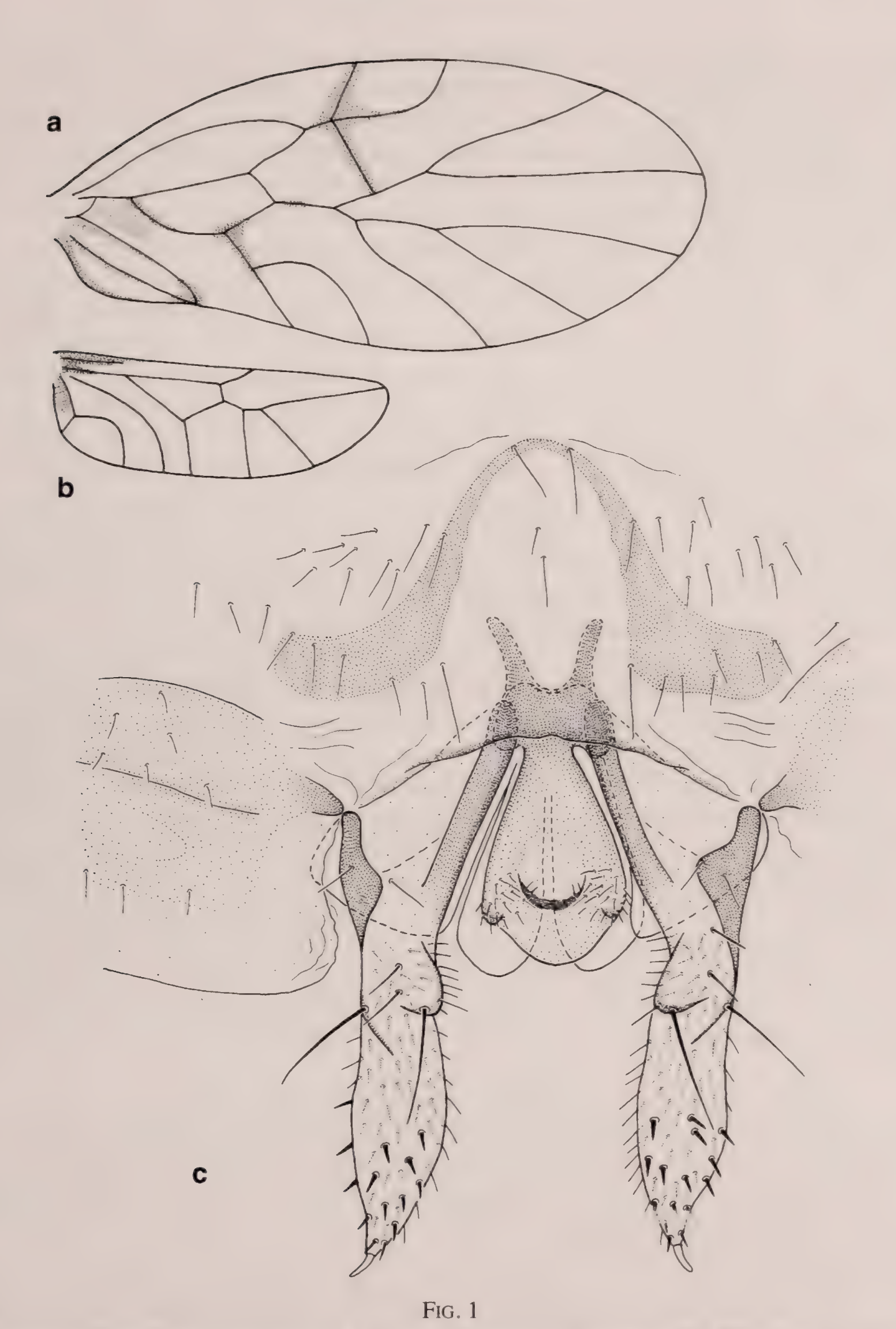



FIG. 1

*Neotrogla brasiliensis* Lienhard gen. n., sp. n., female: (a) Forewing. (b) Hindwing. (c) Subgenital plate and ovipositor valvulae with right ventrolateral parts of clunium, ventral view.

them with a long seta on a ventro-internal protuberance (Fig. 10b:4') about in middle of its length and with a similar seta on outer margin (Fig. 1c). Other pilosity of this ovipositor valvula (Fig. 1c): a claw-like spine on tip (Fig. 10b:6); ventrally numerous

short stout spine-like setae in apical part and some longer hairs in basal half; numerous fine hairs on dorsal surface (represented by dotted lines in Fig. 1c). Valvula articulated near anterolateral margin of clunium by a condyle formed by its wavy marginal sclerotization; sclerotized inner margin of basal part of the valvula elongate and medially articulated to the above mentioned bifurcate sclerite at the base of the posterior lobe of the subgenital plate (Fig. 1c). Dorsally of the posterior lobe of the subgenital plate and of the basal part of the external gonapophyses two pairs of glabrous, apically rounded, membranous lobes present (Fig. 1c; homologuous to ventral and dorsal gonapophyses?). Spermapore region with an elongate gynosome (length about 0.8 mm), as described in the generic diagnosis (Figs 2d, f; 10b, c). Posterior sac of the gynosome (Fig. 10b:9), bearing the spermapore at its tip (Fig. 10b:8), *in situ* slightly ventrally curved (Fig. 2d) with its anterior opening (Fig. 10b:10) situated dorsally, at the base of the anterior rod (Fig. 10b:11"); blister-like part of the gynosome trilobate (Fig. 2f), the lateral lobes (Fig. 10b:12") membranous and finely denticulate, the dorsomedian lobe (Fig. 10b:13) somewhat asymmetrical (slightly bent to the left) and bearing numerous sclerotized denticles and ridges. Wall of the spermatheca thin, bearing small pores and a plate with characteristically arranged sclerotized wrinkles near the origin of the spermathecal duct (Fig. 2e). Spermatophores elongately oval, with a relatively long and more or less curved neck (Fig. 2e).

Male terminalia: Epiproct simple (Fig. 3c). Paraproct with a well-differentiated transversal fold between sense cushion and hindmargin and a relatively long ventral lobe; sense cushion as in the female, posteroventrally with some sclerotized wrinkles (Fig. 3b). Hypandrium simple (Fig. 3d), *in situ* ventrally rounded and almost dome-shaped, weakly sclerotized (some sclerotization also visible on 8th sternite), with two posterolateral pilose areas; the weakly sclerotized aedeagal arch usually only visible through hypandrium after clearing the terminalia. Phallosome strongly simplified and largely membranous (Fig. 3e), laterally towards the posterior margin of the hypandrium with some bulged membranous structures (see also Fig. 7e), between them the broadly rounded simple aedeagal arch (Fig. 10c:14), bearing a smooth apical thickening. Membranous posterior half of the endophallus delimited by the aedeagal arch, anterior half with a median zone of sclerotized papillae forming a longitudinal channel between the ejaculatory duct (= de) and the anterior end of the aedeagal arch (Figs 3e, 10c:15).

*Nymph*: As described for *Sensitibilla strinatii* Lienhard and *Afrotrogla oryx* Lienhard (see Lienhard, 2000, 2007 and Fig. 2a), but with a longitudinal row of articulated spines on anterior face of forefemur and with the following pattern of leg trichobothria: 2 on each tibia, 1 on second article of hindtarsus, 1 on second article of midtarsus (see generic diagnosis).

MEASUREMENTS

*Female holotype*: BL = 3.7 mm; FW = 4.5 mm; HW = 2.2 mm; F = 1060 $\mu$m; T = 1610 $\mu$m; t1= 705 $\mu$m; t2 = 155 $\mu$m; t3 = 166 $\mu$m; Ant (damaged); IO/D = 2.5.

*Male allotype*: BL = 3.6 mm; FW (damaged); HW = 2.2 mm; F = 1070 $\mu$m; T = 1700 $\mu$m; t1-t3 (damaged); Ant (damaged); IO/D = 2.4.

ETYMOLOGY: The specific epithet refers to Brazil, the country of the type locality.

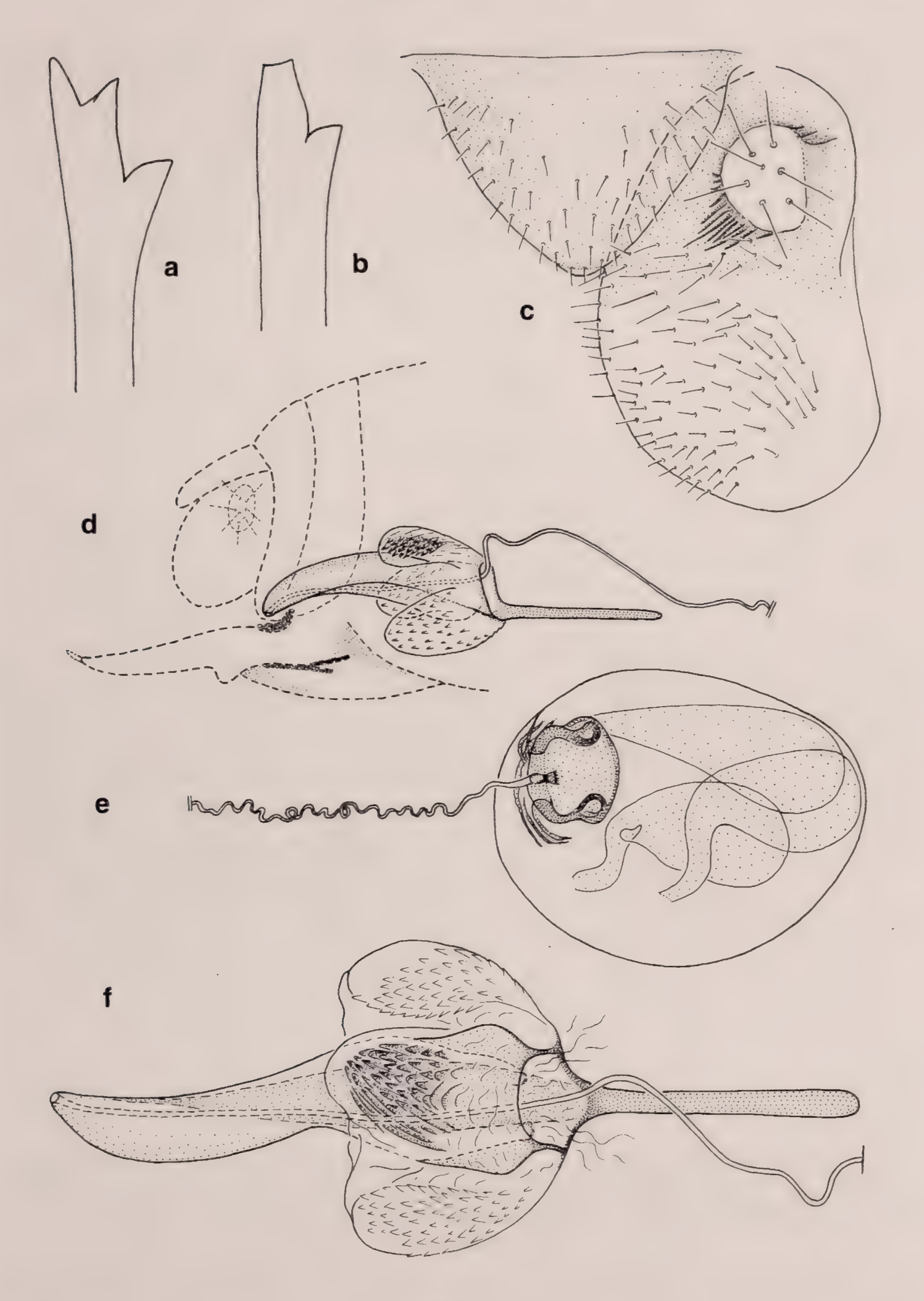



FIG. 2

*Neotrogla brasiliensis* Lienhard gen. n., sp. n.: (a) Lacinial tip, nymph. (b) Lacinial tip, female. (c) Epiproct and right paraproct, female. (d) Abdominal apex of female (interrupted line, schematic), with gynosome, lateral view. (e) Spermatheca (continuation of Fig. 2d), containing three spermatophores. (f) Gynosome, dorsal view (posterior part slightly asymmetrical due to slide mounting).

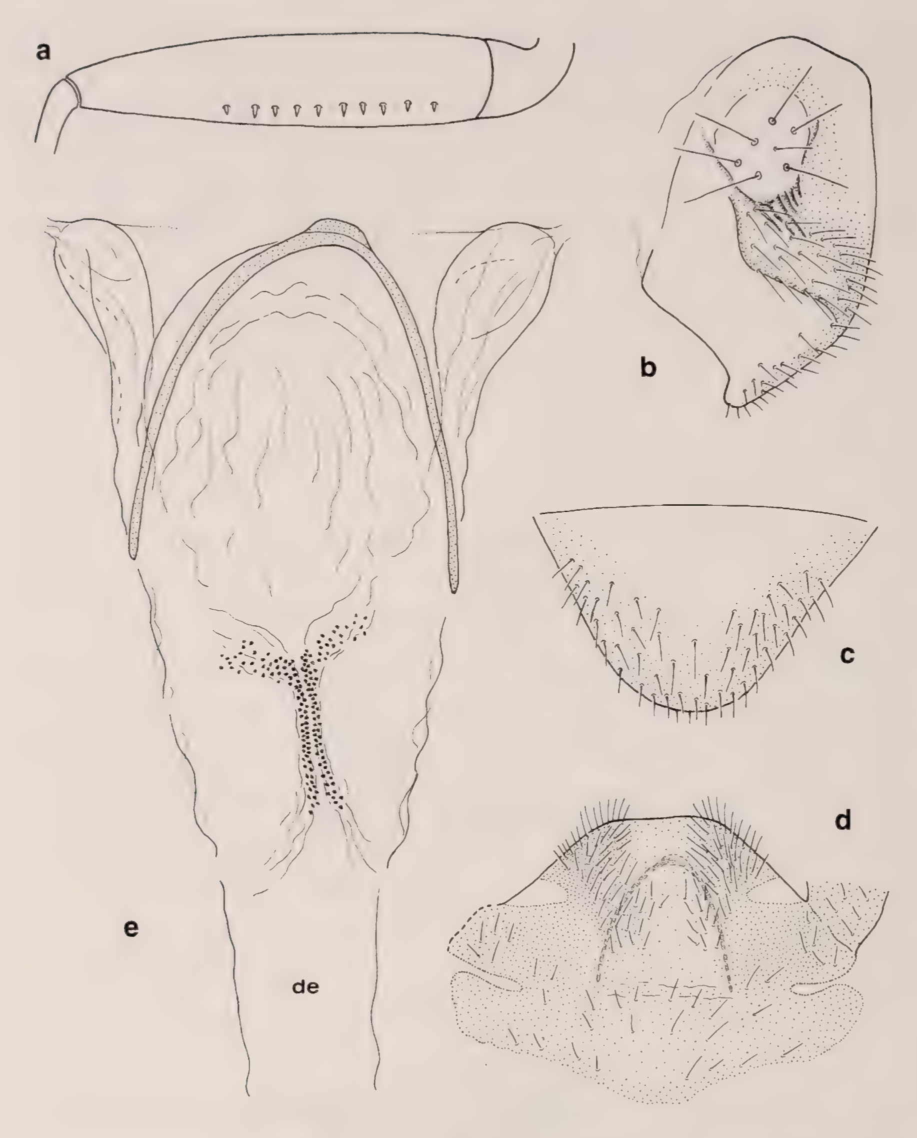



FIG. 3

*Neotrogla brasiliensis* Lienhard gen. n., sp. n., male: (a) Anterior face of forefemur with row of small spines. (b) Left paraproct. (c) Epiproct. (d) Hypandrium, ventral view (aedeagal arch visible through hypandrium). (e) Phallosome, ventral view (de: ductus ejaculatorius).

DISTRIBUTION: At present this species is known from three caves situated in the Peruaçu river valley. This area is located in the north of Minas Gerais State, between the townships of Januária and Itacarambi (Fig. 11). The area is nestled in a transitional area of two Brazilian phytogeographic domains: Cerrado and Caatinga (IBGE, 1993). These domains include several sub-types of vegetation presenting different levels of conservation, with most of them being well preserved. The limestone is part of the

Bambuí Speleological province. According to Piló (1997), the caves of the area can be divided in two main groups: the hydrologically active caves, directly related to the Peruaçu River (such as Janelão cave) and the dry caves positioned above the phreatic level. The dry caves are located in smaller canyons perpendicular to the course of the Peruaçu river (such as Caboclo cave), in residual outcrops or even in outcrops of the main canyon (such as Ossos cave). The three caves where the specimens of *N. brasiliensis* were collected are quite different, indicating that the species might not be adapted to any particular conditions. The area has dozens of caves. Since only few of these caves were prospected by biological surveys, it is possible that the species distribution is wider.

DISCUSSION: See discussion under *N. truncata*.

***Neotrogla aurora*** Lienhard sp. n. Figs 4-7

HOLOTYPE: ISLA, ♀, Brazil (Tocantins), Aurora do Tocantins, cave "Gruta Biritite", 5.i.2009, leg. R. A. Zampaulo.

PARATYPES: 1♂ ISLA; 1♂, 1♀ MHNG; same data as for holotype. – 1♀ ISLA; 1♀ MHNG; Brazil (Tocantins), Aurora do Tocantins, cave "Gruta Asa Branca 1", 7.i.2009, leg. R. A. Zampaulo. – 1♂, 1♀ ISLA; 1♀ MHNG; 1♀ SEHU (for DNA extraction); Brazil (Tocantins), Aurora do Tocantins, cave "Gruta Couve-Flor", 7.i.2009, leg. R. A. Zampaulo.

DESCRIPTION

*Male and female*: See generic diagnosis and description of the type species, with the following differences. Pigmentation of wing membranes similar to that of *N. brasiliensis* but somewhat less extensive (Fig. 4) or even almost absent. Antenna with 13-14 segments, i.e. scape, pedicel and an apparently slightly variable number of flagellomeres (Note: Two intact antennae have been observed. One of them is the 14-segmented left antenna of the holotype. The 13-segmented antenna belongs to a female paratype. Both are considered as intact because the last flagellomere is slightly tapering to a regularly rounded tip and bears a conspicuous terminal sensillum).

Female terminalia: Posterior lobe of the subgenital plate (Fig. 5) apically clearly trilobate. Lateral lobes pilose, median lobe glabrous but densely covered by fine microtrichia or very small denticles. The more or less regularly sclerotized central zone of the posterior lobe of the subgenital plate almost reaching its base, in basal half with a field of tubercles. Both pairs of dorsal membranous lobes (ventral and dorsal gonapophyses?) almost completely covered by the basal part of the external gonapophyses and by the posterior lobe of the subgenital plate (Fig. 5). Gynosome (length about 0.7 mm) similar to that of *N. brasiliensis*, but mediodorsal lobe of its trilobate blister-like part strongly bent to the left (Fig. 6). Wrinkled plate of spermathecal wall (Fig. 7c) similar to that of *N. brasiliensis*. Spermatophores not observed.

Male terminalia: Paraproct with a relatively short ventral lobe (Fig. 7f). Smooth apical thickening of the aedeagal arch relatively wide (Fig. 7e).

*Nymph*: Not known.

MEASUREMENTS

*Female holotype*: BL = 2.75 mm; FW = 4.0 mm; HW = 2.0 mm; F = 865 μm; T = 1380 μm; t1 = 620 μm; t2 = 125 μm; t3 = 140 μm; Ant = 5.2 mm (14-segmented, see description); flagellomeres: f1 = 747 μm; f2 = 663 μm; f3 = 677 μm; f4 = 564 μm; f5 = 380 μm; IO/D = 2.2.

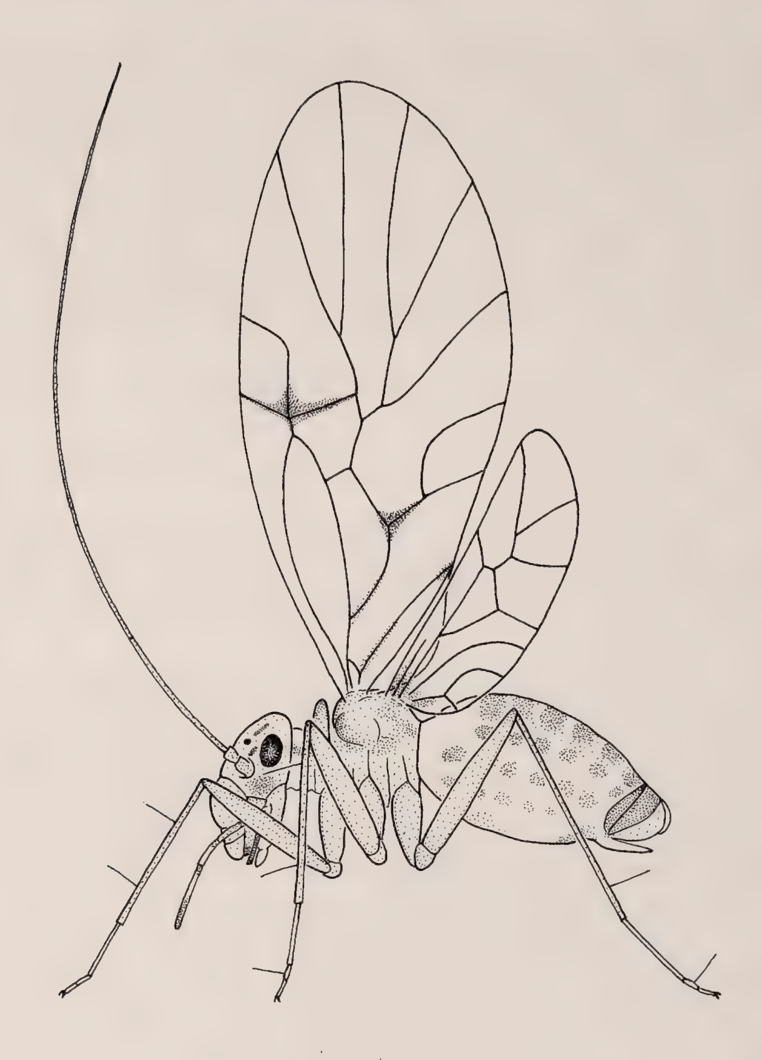


FIG. 4

*Neotrogla aurora* Lienhard gen. n., sp. n., female: Habitus, lateral view; pilosity, except for leg trichobothria, and right appendages not shown (body length 2.6 mm).

*Male allotype*: BL = 2.75 mm; FW (damaged); HW = 2.1 mm; F = 915 $\mu$m; T = 1490 $\mu$m; t1= 677 $\mu$m; t2 = 130 $\mu$m; t3 = 150 $\mu$m; Ant (damaged); IO/D = 2.2.

ETYMOLOGY: The specific epithet, a noun in apposition, refers to the type locality, Aurora do Tocantins.

DISTRIBUTION: At present this species is known from three caves situated in the municipality of Aurora do Tocantins which is located in southern Tocantins State, with an average altitude of 468m (Fig. 11). The area has a tropical climate and is inserted in the Cerrado formation (Brazilian Savana). The limestones of the area are also part of



FIG. 5

*Neotrogla aurora* Lienhard gen. n., sp. n., female: Subgenital plate and ovipositor valvulae with ventrolateral parts of clunium, ventral view.

the Bambuí Speleological province. The caves of this area are mainly small, rarely longer than 200m (Couve-Flor cave 40m, Asa Branca 1 cave 70m, Biritite cave 200m). Six other caves in the area were also prospected, but no Prionoglarididae specimens were found in them. The collection of the *N. aurora* specimens was made by manual capture during one visit to the study area in the period of 05 to 10 of January of 2009. In all caves they were found near the entrance or in disphotic zones, always associated with rocky layers (cave walls or fallen blocks on the floor). The three caves in which the specimens were observed are distinct, but all of them are dry oligotrophic systems. The main resource in all caves is bat guano, although some piles of faeces of the rodent popularly known as mocó (*Kerodon rupestris*) may be found in some areas of the caves. The main vegetation type outside the caves is pasture, with some fragmented areas of Cerrado formation.

DISCUSSION: See discussion under *N. truncata*.

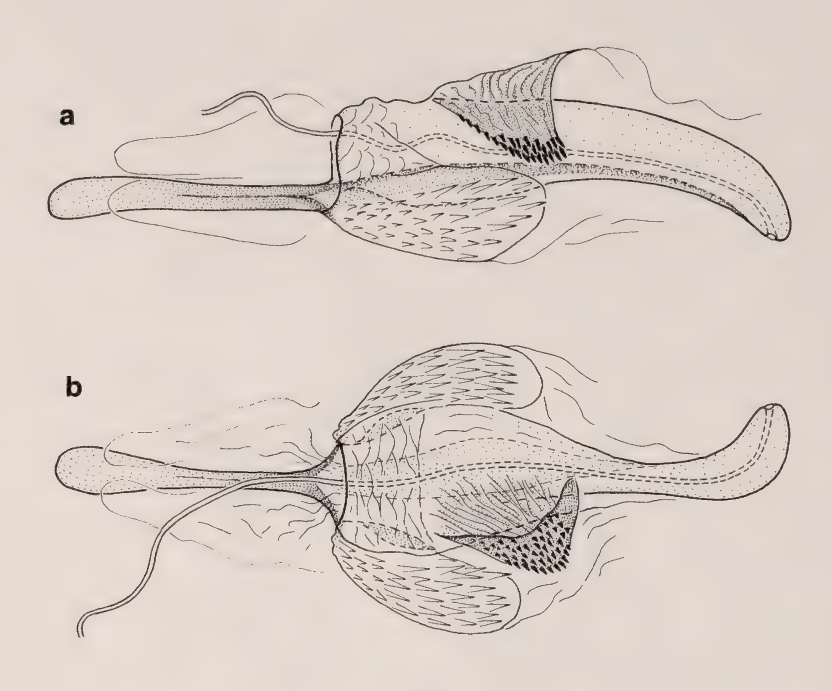



FIG. 6

*Neotrogla aurora* Lienhard gen. n., sp. n., female: (a) Gynosome, lateral view; posterior part at right in the figure. (b) Gynosome, dorsal view (posterior part slightly asymmetrical due to slide mounting).

***Neotrogla truncata*** Lienhard sp. n. Figs 8-9

HOLOTYPE: ISLA, ♀, Brazil (Bahia), Campo Formoso, cave "Toca do Pitu", 10.vii.2008, leg. R. L. Ferreira.

PARATYPES: 1♂ ISLA; 1♀ MHNG; same data as for holotype. – 1♂ MHNG, Brazil (Bahia), Ourolândia, cave "Toca dos Ossos", 31.vii.2007, leg. R. L. Ferreira. – 5♂ ISLA; 1♂ MHNG, 1♂ SEHU (for DNA extraction); Brazil (Bahia), Palmeiras, cave "Gruta Ioiô", 1.i.2008, leg. R. L. Ferreira.

DESCRIPTION

*Male and female*: See generic diagnosis and description of the type species, with the following differences. In forewing (Fig. 8a) fused portion of Rs and M shorter than basal portion of Rs or at most of same length. Pigmentation of wing membranes similar to *N. brasiliensis* but hindwing with a distinct dark patch at the apex of vein R1 (Fig. 8b). Antennae damaged in all specimens examined; intact antenna with more than 11 segments (according to the best-preserved antenna examined, i.e. the right antenna of the allotype, broken beyond the tip of f9).

Female terminalia (Figs 8c, d; 9a): Posterior lobe of subgenital plate relatively short and broadly truncate, with some lateral pilosity; its apical part densely covered by distinct tubercles or denticles; a short transversal fold present medially in its apical half, and anteriorly to it a somewhat less sclerotized smooth central area. Bifurcate sclerite at the base of the posterior lobe of the subgenital plate with relatively short

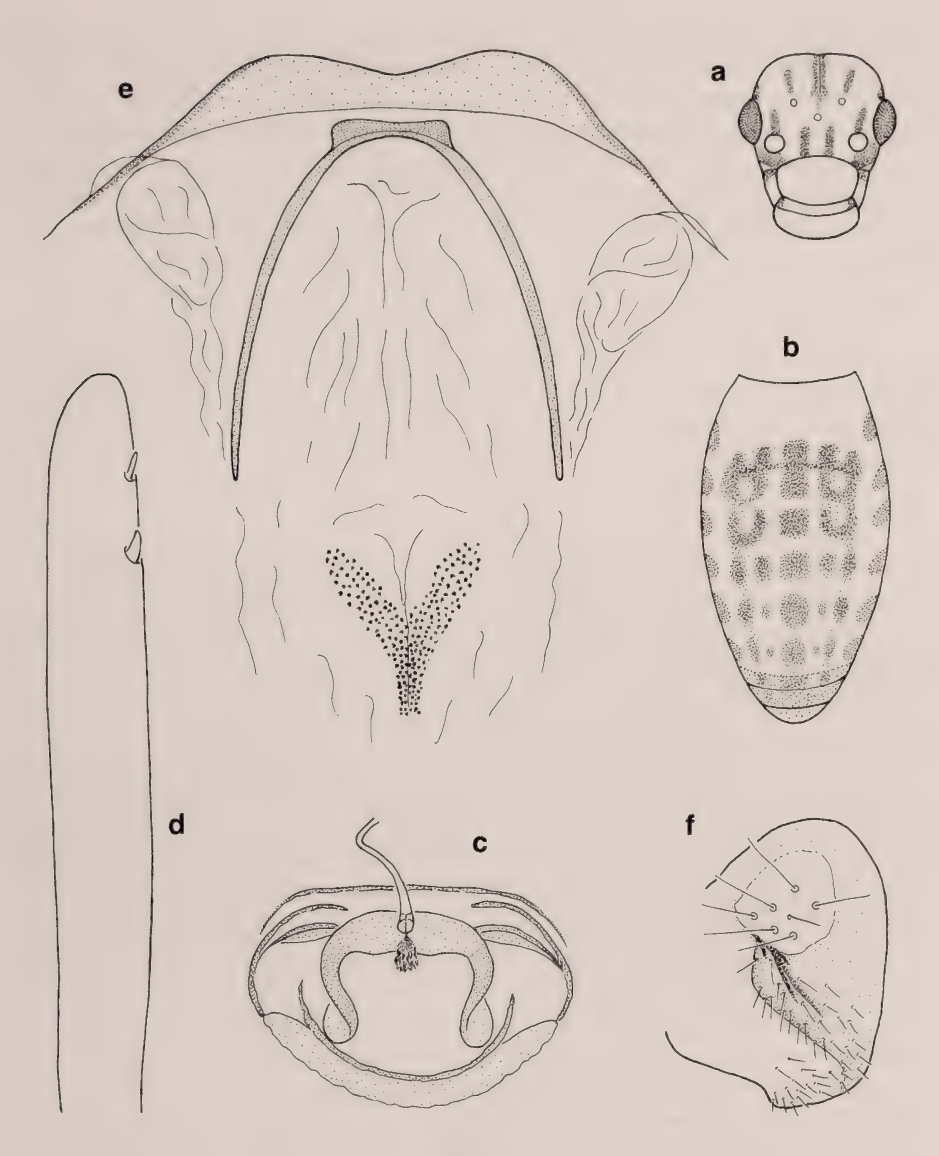



FIG. 7

*Neotrogla aurora* Lienhard gen. n., sp. n.: (a) Head of female, anterior view (antennae and palps not figured). (b) Abdomen of female, dorsal view. (c) Proximal part of spermathecal duct with wrinkled plate of wall of spermathecal sac (compare with Fig. 2e). (d) Apical half of P4 of female, with thin-walled subapical conical sensilla (general pilosity not shown). (e) Posterior margin of hypandrium (pilosity not shown) and phallosome, ventral view.

prongs. Distal part of external gonapophysis broadly foliaceous, ventro-internal protuberance weakly developed, external marginal sclerotization slender, not wavy as in the other two species. Pilosity of this ovipositor valvula similar to that of the other two species but stout ventral setae in apical part usually less spine-like and exceptionally

two long setae present on external margin (see right valvula in Fig. 8d). Internal pair of dorsal membranous lobes (ventral gonapophyses?) clearly protruding from behind the truncate hindmargin of the posterior lobe of the subgenital plate, other pair of membranous lobes (dorsal gonapophyses?) shorter and inconspicuous, almost completely covered by the basal part of the external gonapophyses (Fig. 8d). Gynosome (length 0.63 mm) very characteristic (Figs 8c, 9a), its general shape similar to that of the other two species, but blister-like median part simple, not lobate, entirely membranous, regularly covered by fine scale-like or denticulate sculpture. Wrinkled plate of spermathecal wall and shape of spermatophore similar to *N. brasiliensis* (Fig. 9a).

Male terminalia: Paraproct (Fig. 9c) with a relatively long ventral lobe, lacking the transversal fold present in the two other species. Anterior part of hypandrium (8th sternite) weakly sclerotized (Fig. 9d). Phallosome similar to that of *N. brasiliensis*, but distal thickening of aedeagal arch bearing a fine sculpture of tubercles and short transversal ridges (Fig. 9b).

*Nymph*: Not known.

MEASUREMENTS

*Female holotype*: BL = 3.2 mm; FW = 4.0 mm; HW = 2.0 mm; F = 988 $\mu$m; T = 1520 $\mu$m; t1= 670 $\mu$m; t2 = 150 $\mu$m; t3 = 170 $\mu$m; Ant (damaged); IO/D = 2.5.

*Male allotype*: BL = 2.9 mm; FW = 4.0 mm; HW = 2.0 mm; F = 988 $\mu$m; T = 1510 $\mu$m; t1= 675 $\mu$m; t2 = 140 $\mu$m; t3 = 160 $\mu$m; Ant (damaged); IO/D = 2.6.

ETYMOLOGY: The specific epithet (truncatus, -a, -um) refers to the truncate posterior lobe of the female subgenital plate.

DISTRIBUTION: At present this species is known from three caves situated in the state of Bahia, near the municipalities of Campo Formoso, Ourolândia and Palmeiras (Fig. 11). The area is located in the Brazilian Caatinga, a semi-arid vegetal formation (IBGE, 1993). The caves are part of distinct carbonate domains, the Una carbonate province and the Caatinga limestones (see comments in General Discussion: Biogeography). The environment outside the caves is extremely dry and the degree of human impact is quite variable. The collections were done manually in one visit to each cave. Although some of the caves (Ioiô and Pitu caves) have subterranean lakes or ponds, the specimens were always found in the dry areas of the caves. Ioiô cave (length about 4 km) and Ossos cave (10 km) are considered as long caves, Pitu cave is smaller (about 500m). The specimens were always associated to areas near the cave entrance. *N. truncata* is the most widely distributed species of the genus (Fig. 11). Although the individuals were only found in few caves, the species certainly has a more extensive distribution, since there are hundreds of caves located in the same area.

DISCUSSION: The females of the three species of *Neotrogla* are easy to distinguish. Based on the similar structure of the gynosome and the subgenital plate *N. brasiliensis* and *N. aurora* seem to be more closely related to each other than to *N. truncata*. In the latter the gynosome is much simplified and the posterior lobe of the subgenital plate is short and apically truncate, not elongate and apically more or less trilobate as in *N. aurora* and *N. brasiliensis*. The central zone of this lobe is characteristically structured in each of the three species. The median lobe of the trilobate

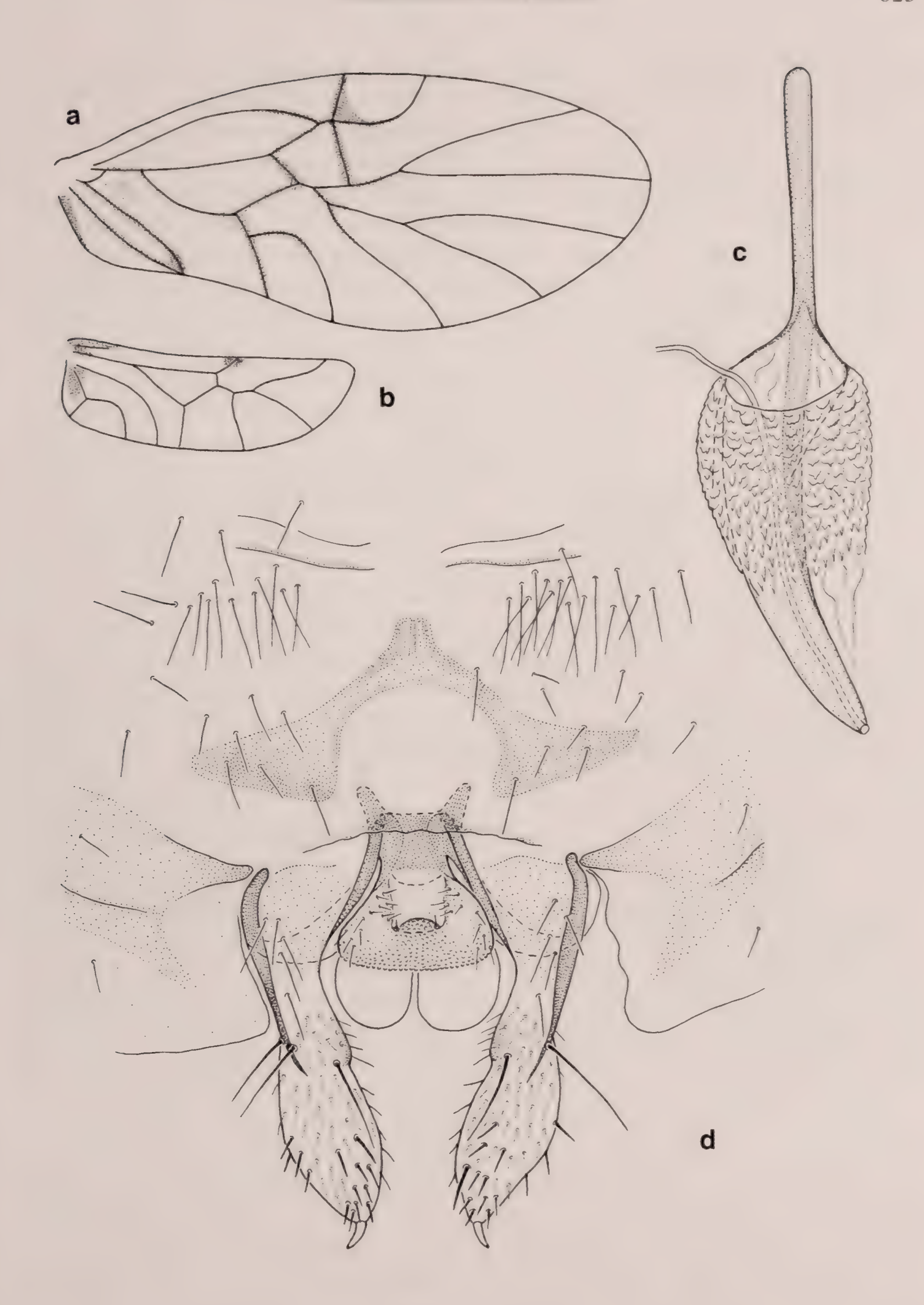



FIG. 8

*Neotrogla truncata* Lienhard gen. n., sp. n., female: (a) Forewing. (b) Hindwing. (c) Gynosome, dorsal view (posterior part downwards directed in the figure, slightly asymmetrical due to slide mounting). (d) Subgenital plate and ovipositor valvulae with ventrolateral parts of clunium, ventral view.

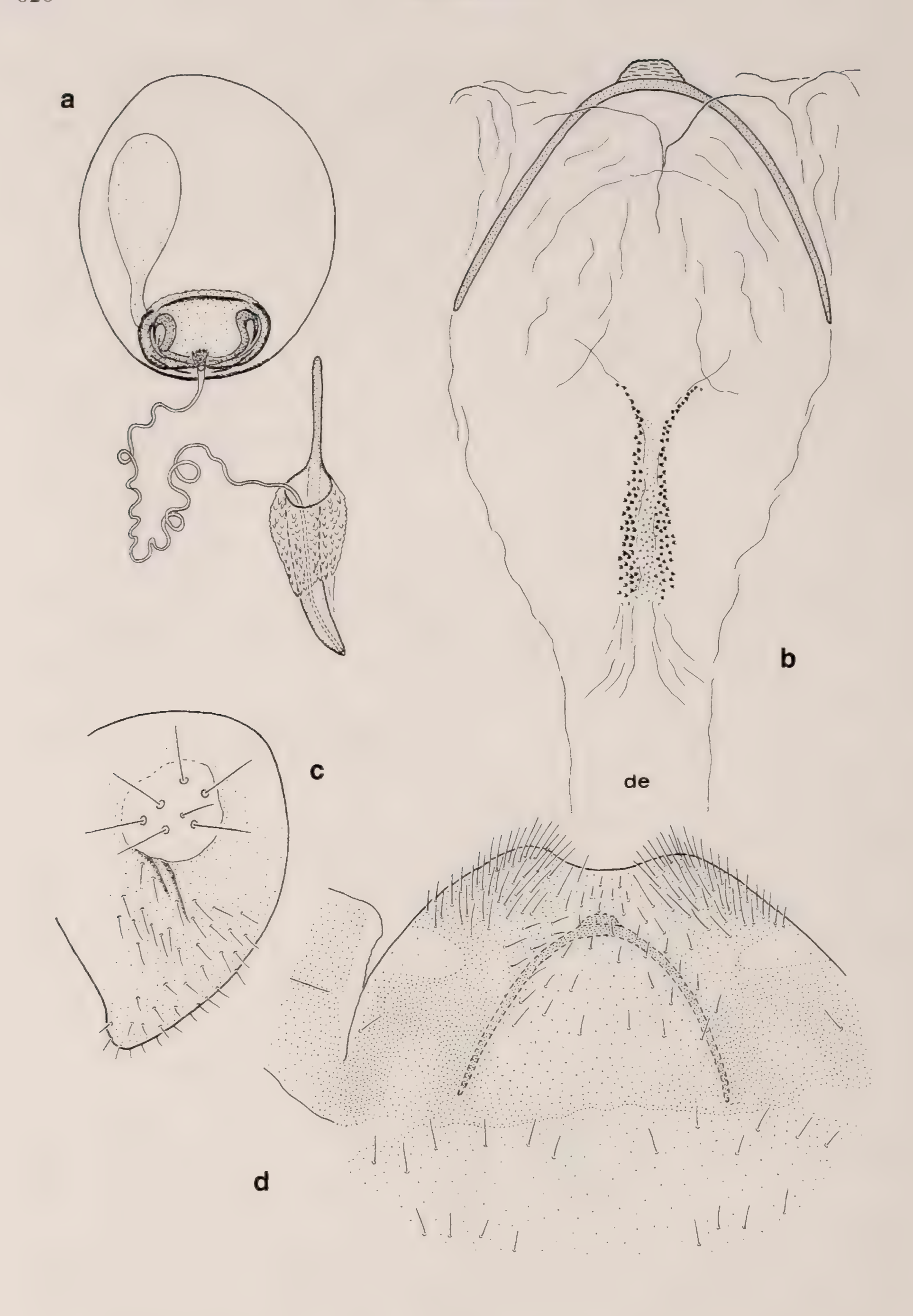



FIG. 9

*Neotrogla truncata* Lienhard gen. n., sp. n.: (a) Gynosome and spermatheca, containing one spermatophore. (b) Phallosome, ventral view (de: ductus ejaculatorius). (c) Left paraproct of male. (d) Hypandrium, ventral view (aedeagal arch visible through hypandrium).

blister-like zone of the gynosome is only very weakly asymmetrical in *N. brasiliensis* but strongly bent to the left in *N. aurora*; in *N. truncata* the blister-like zone of the gynosome is simple and not subdivided into lobes.

The males of the three species of *Neotrogla* are very similar. In *N. brasiliensis* and *N. aurora* the paraproct bears a transversal fold reaching from the sense cushion to hindmargin. This fold is not developed in *N. truncata*. In the latter the distal thickening of the aedeagal arch is finely sculptured while it is smooth in *N. brasiliensis* and *N. aurora*. The males of these two closely related species are particularly difficult to distinguish. In *N. aurora* the ventral lobe of the paraproct (Fig. 7f) seems to be somewhat shorter and the apical thickening of the eadeagal arch (Fig. 7e) slightly wider than in *N. brasiliensis* (Fig. 3b, e). However, nothing is known about intraspecific variability of these characters. The shape of the hindmargin of the hypandrium, which can be straight (Fig. 3d) or slightly concave (Figs 7e, 9d), seems to exhibit considerable intraspecific variation, but this is probably mostly due to position after slide-mounting.

The colouration of the three species is very similar, but in the hindwing of *N. truncata* a distinct brown patch seems always to be present apically on vein R1 (Fig. 8b). This patch is absent or very weakly developed in the other two species.

Biometrically both sexes of each of the three species are very similar. With a body length of 2.5-3.0 mm ($\bar{x}$=2.73, n=8) *N. aurora* seems to be slightly smaller than the closely related *N. brasiliensis* (BL 3.0-3.7 mm, $\bar{x}$=3.41, n=8). The relative length of the fused portion of Rs and M veins in forewing could be an additional character to distinguish *N. truncata* (fused portion shorter than basal portion of Rs or at most of same length, see Fig. 8a) from the two other species (fused portion longer than basal portion of Rs, see Figs 1a and 4).

## GENERAL DISCUSSION

### Morphology

Several morphological structures observed in Speleketorini (see A) and Sensitibillini (see A, B, C) are unique in Psocoptera: (A) presence of trichobothria on legs; (B) external gonapophyses mediobasally joined (fused or articulated, see Phylogenetics) to the posterior lobe of the subgenital plate and bearing a spinose distal process; (C) spermapore with complex accessory structures partly enclosing the spermathecal duct. These structures have been described and discussed by Lienhard (2000, 2007). However, the very particular differentiation of the spermapore region in *Neotrogla* deserves some additional comment.

In female psocids the spermatheca, the spermathecal duct, its opening (spermapore sensu Badonnel, 1970) and the spermapore region are differentiations of the 8th abdominal sternum (Bitsch, 1979). The spermapore region is the area surrounding the opening of the spermathecal duct, it can be membranous or more or less sclerotized (gonopore plate or internal plate *sensu* Yoshizawa, 2005). Traditionally it has been regarded as belonging to the 9th sternum (Badonnel, 1970; Mockford, 1993; Lienhard, 1998; Yoshizawa, 2005) but according to Bitsch (1979) it is situated on the posterior part of the 8th sternum.

A very particular "penis-like" structure of the spermapore region has been described in detail for the new genus *Neotrogla* (see generic diagnosis and species

descriptions), and the new term "gynosome" has been introduced, in analogy to the term phallosome, traditionally used in Psocoptera for the male copulatory organ (Badonnel, 1970). A similar structure was described some years ago for the genus *Afrotrogla* by Lienhard (2007). The schematic representation of these structures *in situ* for *Afrotrogla* and *Neotrogla* (Fig. 10a, b, interrupted lines), showing their position relative to the subgenital plate and the ovipositor valvulae, strongly suggests their homology (compare also detailed figures for *Neotrogla* spp. in the present paper and for *Afrotrogla* spp. in Lienhard, 2007). Therefore we propose to use the term gynosome also for the particularly differentiated spermapore region of *Afrotrogla*. In both genera the gynosome consists of a longitudinal membranous or slightly sclerotized sac (Fig. 10:9), enclosing the distal part of the spermathecal duct (Fig. 10:7) and bearing the spermapore at its tip (Fig. 10:8). The spermathecal duct leaves this sac anteriorly by a relatively wide circular opening (Fig. 10:10) situated dorsally of the longitudinal sclerotization which reinforces the sac ventrally (Figs 2d, 6a, 10:11). *In situ* the tip of the gynosome (broadly rounded in *Afrotrogla*, subacute in *Neotrogla*) is situated mediodorsally of the posterior lobe of the subgenital plate (Fig. 10:2). In *Neotrogla* the gynosome (Fig. 2d) is elongate and slender, bearing a denticulate and sometimes lobate blister-like zone about in the middle of its length (Fig. 10b:12",13) and ventrally a simple sclerotized anterior rod (Fig. 10b:11"). In *Afrotrogla* the longitudinal medio-ventral sclerotization is posteriorly prolonged towards the tip of the sac (Fig. 10a:11) and its anterior part, which corresponds to the simple anterior rod of *Neotrogla*, is a relatively short paired apodeme (Fig. 10a:11'). In *Afrotrogla* the blister-like zone is absent; but on each side of the sac there is a movable longitudinal strut (Fig. 10a:12') anteriorly joined with the paired medioventral sclerotization (see also Lienhard, 2007: figs 4g, 6d). In both genera, the width of the bifurcate sclerotizaton (Fig. 10:3) at the base of the posterior lobe of the subgenital plate (Fig. 10:2) apparently corresponds to the width of the sac of the gynosome (Fig. 10:9), i.e. bifurcate structure (Fig. 10:3) largely opened in *Afrotrogla*, narrowly forked in *Neotrogla*. Figure 10a represents the type species, *Afrotrogla oryx*; in *A. maraisi* the bifurcate sclerite at the base of the posterior lobe of the subgenital plate is not differentiated and the sac of the gynosome is posteriorly very broadly rounded (see Lienhard, 2007: fig. 6d).

Lienhard (2007) has already presented a hypothesis of functional complementarity between the complex gynosome and the strongly simplified phallosome in *Afrotrogla*, suggesting the transfer of the usual functions of a normally sclerotized phallosome of Trogiomorpha (i.e. establishement of close grip of male and female genitalia during sperm transmission) towards the gynosome. In Fig. 10c we propose here a corresponding hypothesis for *Neotrogla*, suggesting the insertion, during copulation, of the "penis-like" gynosome into the male phallosome through its papillate endophallic channel (Fig. 10c:15). It is evident that direct observations of specimens in copula are necessary to test this "topsy-turvy" hypothesis.

## PHYLOGENETICS

Due to their basal position within Trogiomorpha and their similarity to fossils of this suborder, based on a plesiomorphic wing venation, the extant prionoglaridids are considered as "living fossils" (Lienhard, 2007). However, the different clades of

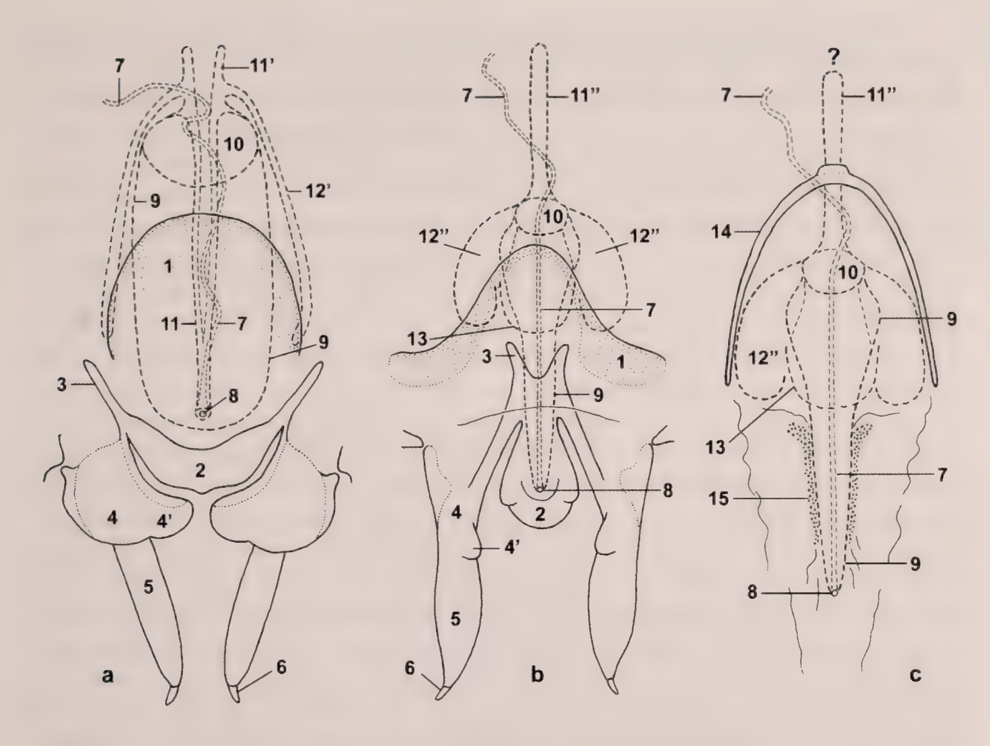



FIG. 10

Schematic genitalia of the type species of the genera *Afrotrogla* and *Neotrogla*, ventral view: (a) *Afrotrogla oryx* Lienhard: gynosome *in situ* with distal part of spermathecal duct (interrupted line), subgenital plate and ovipositor valvulae (based on Lienhard, 2007: fig. 4g). (b) *Neotrogla brasiliensis* Lienhard gen. n., sp. n.: ditto (based on Figs 1c and 2f). (c) *Neotrogla brasiliensis* Lienhard gen. n., sp. n.: hypothetical position of gynosome (interrupted line) inserted into phallosome during copulation (based on Figs 2f and 3e); the question mark indicates the strictly hypothetical nature of this figure. – Morphological details: (1-6) Female, subgenital plate and ovipositor valvulae: (1) subgenital plate, sclerotized area of anterior part; (2) subgenital plate, posterior lobe; (3) bifurcate sclerotization at the base of the posterior lobe of the subgenital plate; (4) external gonapophysis, basal part, with (4') its internal lobe or protuberance; (5) external gonapophysis, distal process; (6) external gonapophysis, claw-like apical spine. (7-13) Female, spermathecal duct and gynosome: (7) spermathecal duct; (8) spermapore on tip of gynosome; (9) gynosome, sac enclosing distal part of spermathecal duct; (10) gynosome, anterior opening of gynosomal sac; (11) gynosome, longitudinal ventral sclerotization, anteriorly differentiated as (11') a paired anterior apodeme or (11") a simple rod; (12) gynosome, lateral structures, differentiated as (12') a sclerotized strut or (12") a lobe of a blister-like zone; (13) gynosome, dorsomedian lobe of blister-like zone. (14-15) Male, phallosome: (14) aedeagal arch; (15) papillate endophallic channel.

this family are characterized by striking autapomorphies and surprising specializations unknown elsewhere in Psocoptera. Characters of Prionoglaridinae have been treated by Lienhard (1988, 1998, 2004) and Lienhard *et al.* (2010), those of Speleketorinae by Lienhard (2000, 2004, 2007). In the following we would like to mention some characters which are probably of crucial importance for the understanding of the phylogeny of the tribe Sensitibillini.

The most striking autapomorphy of the Sensitibillini mentioned by Lienhard (2007) can also be observed in the new genus *Neotrogla*, i.e. the presence of tarsal trichobothria, unique not only in Psocodea but in insects in general. The African representatives of the tribe, the genera *Sensitibilla* and *Afrotrogla*, have one trichobothrium on the second article of hindtarsus. In addition to this, *Neotrogla* has one trichobothrium also on the second article of midtarsus (Fig. 4). We consider the presence of this additional tarsal trichobothrium as an autapomorphy of *Neotrogla*. The very particular structure of the ovipositor, considered as another important autapomorphy of the African Sensitibillini by Lienhard (2007), is also present in the new genus. The external gonapophsis has a spinose distal process (Fig. 10:5) bearing a claw-like apical spine (Fig. 10:6). Mediobasally this ovipositor valvula is joined to the posterior lobe of the subgenital plate (Fig. 10:2) by fusion (in *Sensitibilla*) or articulation (in *Neotrogla*, see Fig. 1c, and in the type species of *Afrotrogla*, *A. oryx*; in *A. maraisi* the situation is not clear, because the laterobasal sclerotization of the posterior lobe of the subgenital plate is not differentiated in this species; see Morphology). These synapomorphies shared by the African genera and the Neotropical genus *Neotrogla* support the assignement of the latter to the tribe Sensitibillini. Within this tribe, *Sensitibilla* is characterized by the autapomorphic presence, on the spermathecal wall, of a kidney-shaped plate bearing a pair of short spines (see Lienhard, 2007: fig. 8) and by the reduction of vein M2 in the hindwing. On the other hand, *Afrotrogla* and *Neotrogla* show the following striking synapomorphies of genitalia which support their assignement to a clade forming the sister-group of *Sensitibilla*: in female, presence of a gynosome (see Morphology); in male, phallosome strongly simplified, its sclerotization reduced to a simple aedeagal arch.

The differentiation of sclerotized lateral struts of the gynosome (Fig. 10a:12') and the presence, in female, of a pair of tufts of long sternal setae at about basal one third of the abdomen (see Lienhard, 2007: figs 4c, 6g) can be considered as autapomorphies of *Afrotrogla*. The particular "penis-like" shape of the gynosome, bearing a blister-like median part (Fig. 10b:12",13), and the presence of a papillate channel anteriorly in endophallus (Fig. 10c:15) can be considered as autapomorphies of *Neotrogla*, together with the above mentioned presence of a trichobothrium on second article of midtarsus. The presence of a longitudinal row of small articulated spines on the anterior face of the forefemur seems to be homoplastic in Psocoptera. In the suborder Trogiomorpha this character is present in the prionoglaridids *Speleketor* (see Mockford, 1984) and *Neotrogla* (Fig. 3a), but it has also been reported from some members of the suborder Psocomorpha, belonging to the families Dolabellopsocidae and Amphipsocidae (see Smithers, 1990). A very similar character is also present in some Amphientometae, belonging to the suborder Troctomorpha. However, in the latter cases the conical spines are not articulated setae but rigid spiniform tubercles (see Lienhard, 1998), which are perhaps not homologous to the above mentioned spines.

The presence of a well-developed and more or less sclerotized posterior lobe of the subgenital plate in *Afrotrogla* and *Neotrogla* (Fig. 10:2) can probably also be interpreted as a synapomorphy of these genera, assuming that the short and membranous posterior part of the subgenital plate generally observed in other Trogiomorpha, including *Sensitibilla* (see Yoshizawa *et al.*, 2006), represents the plesiomorphic

character state. The presence, in females, of a pair of long curved subapical hairs on the terminal article of the hindtarsus (see Lienhard, 2007: fig. 4d) is probably also a synapomorphy of *Afrotrogla* and *Neotrogla*; as far as we know, this character has not yet been observed elsewhere in psocids.

It is somewhat doubtful if the two pairs of membranous and glabrous lobes (Figs 1c, 5, 8d), present in *Neotrogla* dorsally of the posterior lobe of the subgenital plate and of the basal part of the external gonapophyses (and absent in the other Sensitibillini), are really homologous to the ventral and dorsal gonapophyses, which are strongly reduced or absent in all other Trogiomorpha (see Yoshizawa *et al.*, 2006). The presence of these gonapophyses in *Neotrogla* would be a plesiomorphic character. However, these lobes could also be an autapomorphic structure of Neotrogla, not homologous to the ventral and dorsal gonapophyses and perhaps functionally related to the very particular gynosome present in this genus.

Lienhard (2007) mentioned the surprisingly low and apparently variable number of antennal segments in Speleketorinae and suggested that this character could constitute an autapomorphy of this subfamily. The plesiomorphic character state, present in all other Trogiomorpha, would be an antenna with 19 or more segments (i.e. scape, pedicel and at least 17 flagellomeres; see Lienhard, 2007). Flagellomere counts of undoubtedly complete antennae are rare in Prionoglarididae (even completely lacking in the subfamily Prionoglaridinae according to Lienhard, 2007), because their antennae are very thin and fragile, thus broken in most of the specimens available in collections. In the genus *Speleketor* three complete antennae have been observed (Mockford, 1984), each of them with a different number of segments (7, 10, 15). Only two intact antennae of African Sensitibillini are known, one of *Sensitibilla* (13-segmented; see Lienhard, 2000) the other of *Afrotrogla* (11-segmented; see Lienhard, 2007). In *Neotrogla* we were able to observe two intact antennae, comprising 13 and 14 segments (see description of *N. aurora*). Thus, the reduction of the number of flagellomeres and its intrageneric and intraspecific variability have been confirmed by the present observations, suggesting that this character could be interpreted as an autapomorphy of the subfamily Speleketorinae. A certain reduction of the number of flagellomeres is also characteristic for the other suborders of Psocoptera. However, in each of them the variability is very low (i.e. antenna generally 15-segmented in Troctomorpha and 13-segmented in Psocomorpha; see Mockford, 1993). Possible homoplasy of this character relativizes its phylogenetic information within Psocodea.

## Biogeography

Vishnyakova (1980) tentatively placed the origin of the suborder Trogiomorpha in the Early Jurassic. Yoshizawa *et al.* (2006) showed that the prionoglaridids are the most basal members of this suborder and tentatively interpreted their very disjunct distribution (four genera, each of them known from a different zoogeographical region) as Pangaean relicts. As shown by Binford *et al.* (2008) for two genera of cave- and soil-dwelling spiders of the family Sicariidae, the biogeographical pattern observed in Sensitibillini could be due to Western Gondwanan vicariance, admitting that the most recent common ancestor of *Afrotrogla* and *Neotrogla* was present on Western Gondwana before the separation, in the Early Cretaceous, of the African and South

American continents, which was complete about 95 mya (Pitman *et al.*, 1993). This scenario is supported by the present distribution of *Afrotrogla* in caves of SW-Africa (Namibia and northern South-Africa; see Lienhard, 2007 and Lienhard *et al.*, 2010 and map in Lienhard, 2008) and of *Neotrogla* in caves of eastern Brazil (states of Minas Gerais, Tocantins and Bahia; see below and Fig. 11) and by the fact that the molecular tree presented by Yoshizawa *et al.* (2006) suggests that the origin and the diversification of the family is deep. However, Yoshizawa *et al.* (2006) insisted that more data (including clear fossil record evidence) are required for more precise dating of their Trogiomorpha tree. As suggested by Baz & Ortuño (2000), extant cave-dwelling species belonging to basal Trogiomorpha clades may be relicts from Cretaceous tropical forests. Several fossil Trogiomorpha resembling prionoglaridids, due to the presence of a similar plesiomorphic wing venation, were recently described from Early Cretaceous amber from Spain, France and Lebanon (Baz & Ortuño, 2000, 2001; Perrichot *et al.*, 2003; Azar & Nel, 2004). Even if it is not possible to clearly assign any of these fossils to the extant family Prionoglarididae, due to lack of morphological information, there is no doubt that prionoglaridid-like Trogiomorpha were already most diverse in the Early Cretaceous (Perrichot *et al.*, 2003; Azar & Nel, 2004).

This historical scenario represents a hypothesis for the interpretation of the close relationship between the Brazilian genus *Neotrogla* and the African genus *Afrotrogla* within the geologically probably relatively old group of Sensitibillini. On the other hand, the striking morphological similarity of the three modern species of *Neotrogla* suggests a relatively recent specific diversification of this genus in Brazil. The following analysis of the known distribution of these Brazilian cave species may contribute to understanding the relationships indicated by morphology, i.e. *N. brasiliensis* and *N. aurora* much more closely related to each other than to *N. truncata* (see Discussion under *N. truncata*).

The *Neotrogla* species were collected in three distinct carbonate geological groups (Fig. 11). The caves located at Peruaçu river valley (type locality of *N. brasiliensis*) and in Aurora de Tocantins (type locality of *N. aurora*) belong to the Bambuí Group. The carbonate rocks of the Bambuí Group were formed in the Neoproterozoic, dating from around 900 million years. They occur over a vast area in the states of Minas Gerais, Bahia, Goiás and Tocantins and host extensive karst landforms (Auler, 2004). The areal distribution of the carbonate rocks in relation to the surrounding topography forms several physiographic domains, lending distinct morphological patterns on the karst landforms. Although the caves from Peruaçu and Aurora de Tocantins are quite far from each other, it is plausible to assume that they might have some underground continuity (or might have had in the past). Furthermore, most caves located in the areas inbetween those previously mentioned were not sampled and, thus, may also have some populations of the two species.

On the other hand, the caves where *N. truncata* was collected occur in two distinct limestone units: the Una Group (Pitu and Ioiô caves) and the Caatinga Formation (Ossos cave). The Neoproterozoic carbonate rocks of the Una Group occur in the northern half of the state of Bahia, and comprise a series of separate basins divided by quartzite mountain ranges (Auler & Smart, 2003). Most of the carbonate bedrock surface is covered by a thick soil sequence. Surface karst features are represented

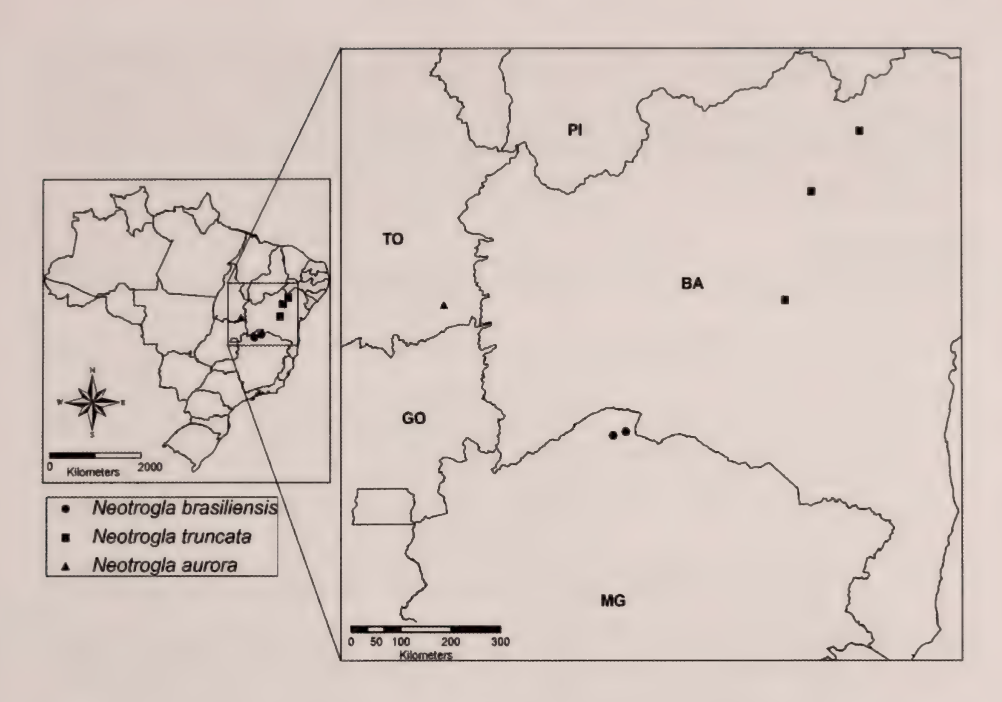



FIG. 11
Currently known geographical distribution of *Neotrogla* spp. in Brazil. States: BA = Bahia, GO = Goiás, MG = Minas Gerais, PI = Piauí, TO = Tocantins.

mostly by dolines, which can be extremely frequent, creating a very uneven terrain. Many of these dolines appear to be due to collapse with later smoothening of the slopes. Speleological research in the area is still in its infancy, and large tracts of carbonate outcrop remain to be checked (Auler, 1999). The freshwater Caatinga Group consists in a rather recent limestone, probably dating from the Pliocene. These limestones occur from the central-west to the northern portion of the state of Bahia, containing some inferred contact zones with the Una limestones. So, it is quite possible that these two domains, although formed in different ages and conditions, are physically connected at present.

The phylogenetic relationship between the three species may be partly explained by the geological formations in which the caves they inhabit are found. The relatively closely related *N. brasiliensis* and *N. aurora* are both known from caves in the Bambuí group of limestones, while *N. truncata* is known from caves in the Una and Caatinga limestones, which are contiguous with each other in some areas, but separated from the Bambuí formations.

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## REFERENCES

AULER, A. S. 1999. Karst evolution and palaeoclimate in eastern Brazil. PhD *Thesis, University of Bristol.*

AULER, A. S. 2004. Bambui Karst. *In*: GUNN, J. (ed.). Encyclopedia of Cave and Karst. *Science Taylor and Francis, New York*, p. 133-135.

AULER, A. S. & SMART, P. L. 2003. The influence of bedrock derived acidity in the development of surface and underground karst: Evidence from the Precambrian carbonates of semi-arid northeastern Brazil. *Earth Surface Processes and Landforms* 28: 157-168.

AZAR, D. & NEL, A. 2004. Four new Psocoptera from Lebanese amber (Insecta: Psocomorpha [sic!]: Trogiomorpha). *Annales de la Société entomologique de France (Nouvelle Série)* 40(2): 185-192.

BAZ, A. & ORTUÑO, V. M. 2000. Archaeatropidae, a new family of Psocoptera from the Cretaceous amber of Alava, Northern Spain. *Annals of the Entomological Society of America* 93(3): 367-373.

BAZ, A. & ORTUÑO, V. M. 2001. New genera and species of empheriids (Psocoptera: Empheriidae) from the Cretaceous amber of Alava, northern Spain. *Cretaceous Research* 22: 575-584.

BADONNEL, A. 1970. Psocoptera (pp. 172-175). *In*: TUXEN, S. L. (ed.). Taxonomist's Glossary of Genitalia in Insects. *Munksgaard, Copenhagen*, 359 pp.

BINFORD, G. J., CALLAHAN, M. S., BODNER, M. R., RYNERSON, M. R., NUÑEZ, P. B., ELLISON, C. E. & DUNCAN, R. P. 2008. Phylogenetic relationships of *Loxosceles* and *Sicarius* spiders are consistent with Western Gondwanan vicariance. *Molecular Phylogenetics and Evolution* 49: 538-553.

BITSCH, J. 1979. Morphologie abdominale des insectes (pp. 291-578). *In*: GRASSÉ, P.-P. (ed.). Traité de Zoologie, vol. 8, fasc. 2. *Masson, Paris*, 600 pp.

GARCIA ALDRETE, A. N. & MOCKFORD, E. L. 2009. A list of Psocoptera (Insecta: Psocodea) from Brazil. *Revista Mexicana de Biodiversidad* 80: 665- 673.

IBGE (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATISTICA) 1993. Mapa de Vegetação do Brasil. Rio de Janeiro, IBGE.

LIENHARD, C. 1988. Vorarbeiten zu einer Psocopteren Fauna der Westpaläarktis. IV. Die Gattung *Prionoglaris* Enderlein (Psocoptera: Prionoglarididae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 61: 89-108.

LIENHARD, C. 1998. Psocoptères euro-méditerranéens. *Faune de France* 83: XX+517 pp.

LIENHARD, C. 2000. A new genus of Prionoglarididae from a Namibian cave (Insecta: Psocoptera). *Revue suisse de Zoologie* 107(4): 871-882.

LIENHARD, C. 2004. *Siamoglaris zebrina* gen. n., sp. n., the first representative of Prionoglarididae from the Oriental Region (Insecta: Psocoptera). *Revue suisse de Zoologie* 111(4): 865-875.

LIENHARD, C. 2007. Description of a new African genus and a new tribe of Speleketorinae (Psocodea: 'Psocoptera': Prionoglarididae). *Revue suisse de Zoologie* 114(3): 441-469.

LIENHARD, C. 2008. Découverte d'étonnants fossiles vivants. *Muséum & Co., Journal du Muséum d'histoire naturelle et du Musée d'histoire des sciences, Genève*, no. 3: 2-4. Online: http://www.ville-ge.ch/mhng/pdf/mus_co_03.pdf

LIENHARD, C. & SMITHERS, C. N. 2002. Psocoptera (Insecta): World Catalogue and Bibliography. *Instrumenta Biodiversitatis (Muséum d'histoire naturelle, Genève)* 5: xli+745 pp.

LIENHARD, C., HOLUSA, O. & GRAFITTI, G. 2010. Two new cave-dwelling Prionoglarididae from Venezuela and Namibia (Psocodea: 'Psocoptera': Trogiomorpha). *Revue suisse de Zoologie* 117 (2): 185-197.

MOCKFORD, E. L. 1984. Two new species of *Speleketor* from southern California with comments on the taxonomic position of the genus (Psocoptera: Prionoglaridae). *Southwestern Naturalist* 29(2): 169-179.

MOCKFORD, E. L. 1993. North American Psocoptera (Insecta). *Flora and Fauna Handbook* 10: XVIII+455 pp. *Sandhill Crane Press, Gainesville, Florida.*

PERRICHOT, V., AZAR, D., NÉRAUDEAU, D. & NEL, A. 2003. New Psocoptera in the Early Cretaceous amber of SW France and Lebanon (Insecta: Psocoptera: Trogiomorpha). *Geological Magazine* 140(6): 669-683.

PILÓ, L. B. 1997. Caracterização regional do carste do vale do rio Peruaçu. *O Carste* 9(2): 22-29.

PITMAN III, W. C., CANDE, S., LABRECQUE, J. & PINDELL, J. 1993. Fragmentation of Gondwana: the separation of Africa from South America (pp. 15-34). *In*: GOLDBLATT, P. (ed.). Biological relationships between Africa and South America. *Yale University Press, New Haven*, viii + 630 pp.

SMITHERS, C. N. 1990. Keys to the families and genera of Psocoptera (Arthropoda: Insecta). *Technical Reports of the Australian Museum* 2: 1-82.

VISHNYAKOVA, V. N. 1980. The historical development of the Insecta. Superorder Psocoidea. Order Psocida. *Trudy Paleontologicheskogo Instituta* 175: 52-57.

YOSHIZAWA, K. 2005. Morphology of Psocomorpha (Psocodea: 'Psocoptera'). *Insecta Matsumurana, New Series* 62: 1-44.

YOSHIZAWA, K. & JOHNSON, K. P. 2006. Morphology of male genitalia in lice and their relatives and phylogenetic implications. *Systematic Entomology* 31: 350-361.

YOSHIZAWA, K., LIENHARD, C. & JOHNSON, K. P. 2006. Molecular systematics of the suborder Trogiomorpha (Insecta: Psocodea: 'Psocoptera'). *Zoological Journal of the Linnean Society* 146: 287-299.

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# Nominal taxa of *Spalerosophis diadema* (Schlegel, 1837) from Iraq to Pakistan – two centuries of confusion (Reptilia: Squamata: Colubrinae)

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**Nominal taxa of *Spalerosophis diadema* (Schlegel, 1837) from Iraq to Pakistan – two centuries of confusion (Reptilia: Squamata: Colubrinae).** - The original descriptions of nominal species-group taxa of *Spalerosophis diadema* (Schlegel, 1837) from Iraq to Pakistan are scrutinized, the status of extant and presumably lost type specimens and alleged original series assessed, scale characters of populations from the Euphrates to the Indus Valley analyzed, and taxonomic implications discussed. The origin of the supposedly missing type material of *Coluber diadema* Schlegel (vicinity of Bushehr, Iran) remains inconclusive. Morphologically, its description best fits *S. d. cliffordii* (Schlegel, 1837) from North Africa to Iraq and Khuzestan (Iran). *S. d. schirasianus* (Jan, 1863) is a distinct subspecies from Turkmenistan and the Zagros Range to Baluchistan (Pakistan). Eastern Diadem snake populations, yet to be properly named, are referred to as *S. d. diadema* auct.

**Keywords:** *Spalerosophis diadema* - species-group - nominal taxa type series - taxonomy - morphology - systematics - type locality.

## INTRODUCTION

*Spalerosophis diadema* (Schlegel, 1837) is a wide-ranging colubrid snake of the semi-arid belt from West Africa to Central Asia and the northwestern Indian Peninsula. Marx (1959), the first reviser of *Spalerosophis* Jan, 1865, assigned Asian populations to the nominate subspecies from India and Pakistan, the Saharo-Arabian *S. d. cliffordii* (Schlegel, 1837), and *S. d. schirasianus* (Jan, 1863) from Turkmenistan and most of Iran to Uzbekistan including the Fergana Valley (Kyrgyzstan, Tadzhikistan) and Baluchistan, Pakistan.

For a while, we felt that *Spalerosophis diadema* can hardly be deemed having been thoroughly studied throughout its entire range of distribution, and in particular the Middle East. A closer look at the original references of nominal subspecies of the Diadem snake that occur in this area (*S. d. diadema*, *S. d. cliffordii*, *S. d. schirasianus*)

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and an evaluation of the pertinent literature, with special emphasis on morphological data, confirm that the systematics and taxonomy of *S. diadema* from the Euphrates and the Caspian Sea to the Indian subcontinent are in need of clarification. This statement holds true despite, and partly due to, a recent contribution on that topic by Baig & Masroor (2008).

Beyond an appraisal of the descriptions and early relevant works on *Spalerosophis diadema* ssp., this study addresses the current set of taxonomic and systematic difficulties encountered in populations from the Middle East to the Indian Peninsula, i.e., focuses on distinctive characters and the homeland of *S. d. diadema* (Schlegel), the eastern distribution limit of *S. d. cliffordii* (Schlegel), and the validity of *S. d. schirasianus* (Jan).

## MATERIAL AND METHODS

### Structure of paper, geographic scope, and data

For the sake of intelligibility, and apart from the presentation of the systematic concept followed in this paper, the results section is split into a historical and an analytical part. The former is purely descriptive, scrutinizes the original publications as well as antecedent and contemporary contributions to, and illustrations of, the nominal species-group taxa under consideration with emphasis on the provenance and morphological features of the type series, and sets forth comments necessary for the understanding of the taxonomic context.

The comparative account analyzes the intraspecific variation of head and body scales (prefrontal, supralabial, perioculars; ventrals, subcaudals, longitudinal dorsal rows). Morphological data compiled in that chapter are from literature. If not indicated in the respective publication, the gender of specimens is inferred from their number of ventrals (see Tb. 2). Populations dealt with basically range from south of approximately 34°30'N (Jabal Hamrin) and east of roughly 43°45'E (Fallujah area) in Iraq to eastern Turkmenistan (Amu Darja) and Pakistan; Marx's (1959) condensed data include one specimen from western Kurdistan. For reasons explained elsewhere (Systematic Concept: second paragraph), Indian references of *Spalerosophis diadema* auct. are not considered in this study.

## TERMINOLOGY

The term 'supranumeral scutes' denotes any scales on the pileus beside the ordinary nine shields usually found in colubrines, and in particular those regularly observed in the prefrontal region. 'Prefrontals' are used as utilized by Jan (1863), i.e., refers to all dorsal head scales between the internasals and the anterior borders of the frontal and supraoculars; laterally, the prefrontals may reach the upper loreal region (Fig. 1B). 'Loreals' are situated on or above a straight line parallel to the mouth from the lower posterior tip of the nostril to the periocular ring; the uppermost loreal, in contact with the prefrontals, usually encroaches to some extent beyond the canthus rostralis (Figs 1A, 2). Scales below this demarcation and bordering the supralabials, but not touching the orbit, are referred to as 'secondary labials'. 'Perioculars' are all scales in contact with the eye except the supraocular plate; the first is the large upper

"preocular" (auct.). The maximum of longitudinal dorsal scale rows in *Spalerosophis* spp. may occur immediately in front of midbody (50% of the total number of ventrals) as exemplified by the type species, *S. microlepis* Jan, 1865 (Schätti *et al.*, 2009a). For the purpose of this study, midbody dorsal scale rows ('msr') denote the maximum along the trunk, and not necessarily the count exactly at midbody.

The interpretation of prefrontal data from literature is tricky. For instance, "eight to 11" and "six to nine" prefrontals for *Spalerosophis d. diadema* auct. and *S. d. schirasianus*, respectively, reported by Minton (1966) are most probably made up of all scutes along the outer border of the larger central prefrontals and may in particular include the uppermost loreal that extends to various degrees onto the pileus (e.g., Jan & Sordelli, 1867: Pl. II; Figs 1A, 2). Furthermore, a printing lapsus cannot be ruled out, as Minton (1966) noted the same range ("eight to 11") in the case of perioculars for the nominate subspecies. Reservations also exist regarding Hellmich's (1959) description of scales in the prefrontal region (see Discussion). The undefined term "frontonasals" sensu Baig & Masroor (2008: Tb. 1) probably refers to larger prefrontals in contact with the internasals. Supplementary "fronto-nasales" or "frontales antérieures" as described by Duméril *et al.* (1854: 678 [footnote], 679) actually refer to identical configurations (Fig. 2) and the terminological distinction is futile. Zugmayer (1905) used "Frontonasalia" instead of internasals.

Günther (1864) reported "about fourteen" supralabials but only thirteen are shown in his illustration (Pl. XXI.G). Werner's (1936) "Postocularia" actually also contain all suboculars (auct.) and were converted into perioculars by adding two scales (preoculars auct.), which is a moderate position. The definiton of "ocular scales in the ring about the orbit" (Schmidt, 1930) or "scales in ocular ring" (Marx, 1959) is ambiguous; it remains unclear whether or not these terms comprise, for example, the supraocular plate, and Marx's (1959) data encompass circumocular scales not entering the eye (Schätti *et al.*, 2009a).

Ventral data indicated in literature may usually include one or two preventrals. The exceedingly high count "278" in a specimen from "Gilgit" (Boulenger, 1893) is excluded from analysis. Wall's (1911b) report of 251 ventrals for an alleged male from Chitral (coll. "15-3-10") is considered to belong to a female; this is also the case with a Diadem snake ("♂", 236 ventrals) from "Harmaleh" (Goteysh, 31°57'N 48°34'E), Khuzestan (Hellmich, 1959). "207" ventrals and "60" subcaudals in a probable male from Fallujah (Corkill, 1932) are outliers, most likely based on a counting or printing error (217?) and, respectively, an incomplete tail. This may also be true for "sixty-six pairs" of subcaudals in a specimen from "Karmán" (Blanford, 1876; see Boettger, 1888). "27" subcaudals reported by Afrasiab & Ali (1989) were changed to 72. The dorsal scale count "26" mentioned by Khan (1986) had most probably not been taken at midbody; even values ("26" and "28") in Zugmayer (1905), Mertens (1956), and Baig & Masroor (2008) are understood to correspond to a maximum along the trunk of at least 27 and 29, respectively (see above).

## Material examined

We examined the five extant syntypes of *Periops parallelus* Duméril, Bibron & Duméril, 1854 (MNHN 3571-3574 and 1999.8250) and, through courtesy of Ronald de

Ruiter (Leiden), have photographs showing dorsal, lateral (left side) and ventral views of the head as well as the underside of the tail (subcaudals) of two paralectotypes of *Coluber cliffordii* Schlegel, 1837 (RMNH 467A-B) registered as "syntypes" from "Tripoli". To conclude from the aberrant condition of the supralabials (i.e., seventh in contact with eye on left side) and the total number of secondary labials and loreals (six) as well as size, the letters 'a' and 'b' are in reversed order vis-à-vis Kramer & Schnurrenberger's (1963) notation. Most probably, these individual labels were attached after 1963; we denote the specimens in line with the RMNH register.

### Acronyms

Acronyms mentioned in the text are BMNH (The Natural History Museum [British Museum (Natural History)], London), FMNH (Field Museum of Natural History, Chicago), MCZ (Museum of Comparative Zoology, Harvard University, Cambridge), MHNG (Muséum d'Histoire naturelle, Genève), MNHN (Muséum National d'Histoire Naturelle, Paris), MSNG (Museo Civico di Storia Naturale 'Giacomo Doria', Genova), MSNM (Museo Civico di Storia Naturale, Milano), PMNH (Pakistan Museum of Natural History, Islamabad), RMNH (Rijks Museum voor Natuurlijke Historie [Nationaal Natuurhistorisch Museum, National Museum of Natural History] 'Naturalis', Leiden), SK (collection of the late Eugen Kramer, now mostly stored in the MHNG), SMF (Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt/Main), and USNM (National Museum of Natural History [Smithsonian Institution, United States National Museum], Washington).

## RESULTS

### Systematic Concept

Schmidt (1930) revalidated *Spalerosophis* Jan for *S. microlepis* Jan, 1865 (type species) from West Iran, *S. arenarius* (Boulenger, 1890) of India and Pakistan, and *S. diadema* (Schlegel, 1837) from "Morocco to Turkestan and the Indian Peninsula". Schätti *et al.* (2009a) recently published an appraisal of the genus with a key to the six currently recognized species including *S. atriceps* (Fischer, 1885) from North India and adjacent areas, the Maghrebian *S. dolichospilus* (Werner, 1923), and the remarkable *S. josephscorteccii* Lanza, 1964 only known from the type locality (Galgalo Oasis) in Northwest Somalia (Puntland).

Marx's (1959) nominate subspecies of *Spalerosophis diadema* is made up of "typical *d. diadema*" and "the strikingly different color variety '*atriceps*'" which he believed to be "a synonym of *d. diadema*." Contrary to this widespread view (e.g., Mertens, 1969; Khan, 2006; Hallermann, 2007), we follow Minton (1966) and Baig & Masroor (2008) who consider *Zamenis diadema* ["Var."] *atriceps* Fischer a valid species of the *S. diadema* group sensu Schätti *et al.* (2009a) encompassing *S. arenarius*, *S. diadema*, and *S. dolichospilus*. *S. atriceps* and *S. diadema* unmistakably differ in their respective adult head and body colour pattern (e.g., Wall, 1914: Pl. XXIII; Smith, 1943: Figs 51-52; Minton, 1966: Pls 25.3-27.1) but juveniles and subadults look very similar ("conform to one type", Wall, 1914) and are, at least by the current standard of knowledge, hard to distinguish, in particular from literature data [1]. Sympatry of *atriceps* and *diadema* is confirmed for Pakistan (e.g., Minton, 1966;

Mertens, 1969) but, as a consequence of existing systematic confusion, the presence of *diadema* in India is a matter of disagreement; Baig & Masroor (2008: Fig. 7), for instance, only mapped *atriceps*. To judge from a survey of literature, the Indian distribution range of *Spalerosophis* spp. (*atriceps*, *diadema*) extends to Gujarat (Kutch) in the south, Rajasthan, and east to Uttar Pradesh (Whitaker & Captain, 2004 [as *S. atriceps*]). Specimens from Southeast Nepal briefly discussed in Schätti *et al.* (2009a) belong to *atriceps* as evidenced, for example, by Shah & Tiwari (2004: photograph); however, this picture is from an animal kept by a snake charmer (Karan B. Shah in litt.) and autochthonous records, at least for the Kathmandu Valley, await confirmation. Although the Diadem snake most probably occurs in Northwest India (e.g., Kashmir, Punjab), we refrain from including literature data about *Zamenis* or *Coluber* (auct.) "*diadema*" as documented, for example, from Haryana (Ambala), Rajasthan, and western Uttar Pradesh (Agra) by Boulenger (1893), Constable (1949) or Biswas & Sanyal (1977) because these records (incl. BMNH material, MCZ 3766) are based on subadults (600 mm snout-vent length or less) or specimens without indication of size (Boulenger, 1893).

Schlegel (1837) thought the type locality of *Spalerosophis diadema* to be in the vicinity of Mumbai, India ("environs de Bombay"), but Wall (1914) and Mertens (1940) demonstrated that the original series, first reported and described by Russell (1807), is from the northern part of the Persian Gulf ("from Buchier"). Despite this, Schlegel's (1837) erroneous view regarding the provenance of the type material (see Early Descriptions) found many followers including Schmidt (1939) and his alumnus Marx (1959).

Upon examination of twelve FMNH specimens from the vicinity of Teheran, Schmidt (1939) realized that Iranian populations of *Spalerosophis diadema* are "well distinguished from the so-called *diadema* of Iraq" and declared species status for *cliffordii* and *schirasianus*. Mertens (1940) noted minor differences in colour pattern (dorsal markings not roundish) of Diadem snakes from the Teheran area (SMF material) vis-à-vis two *schirasianus* shown in Jan & Sordelli (1867: Pl. II) ("Die Rückenflecke haben […] eine ziemlich runde Form, die bei meinen Exemplaren nicht in Erscheinung tritt") and referred his specimens to the nominate subspecies because they largely agreed with Russell's (1807) illustration of the lectotype in colour pattern and scale features ("stimmen […] in der Zeichnung wie in der Beschilderung […] weitgehend überein").

Schmidt (1939) ranked *Coluber cliffordii* Schlegel, *C. diadema* Schlegel, and *Periops parallelus schirasianus* Jan as valid species (for reservations see Discussion: penultimate paragraph); this opinion was rarely followed, for instance by Schmidt &

[1]) Minton (1966) observed "keeled" dorsals in *Spalerosophis atriceps* versus smooth or weakly keeled scales in Pakistani *S. diadema*. However, it is not known whether these character states do hold for juveniles and subadults, and literature about *Spalerosophis* spp. from Pakistan and India lacks specific information. The elaboration of distinctive features that apply to smaller specimens is a matter of priority. Apart from the degree of keeling of the dorsal scales, the number of loreal scales (and their distinction from prefrontals) or, for instance, details of the maxillary as the condition of the interspace (present or absent) or the size of the postdiastemal teeth (enlarged or not) are of potential systematic significance within the *S. diadema* complex.

Marx (1957), Khalaf (1960) and Latifi (1991) in the case of *Spalerosophis cliffordi* [sic] and Schmidt (1955) for *S. shirazianus* [sic]. Recently, Trape & Mané (2006) conferred species status to Clifford's Diadem snake because of homogeneous scale characters compatible with literature data for this taxon but clearly different from *S. diadema* ("j'ai basé ma décision sur le fait que ma série de spécimens d'Afrique de l'Ouest était très homogène en compte d'écailles, bien différente de ce qui était publié pour *S. diadema*, mais compatible avec *S. cliffordi* [sic] qui avait été initialement décrit comme une bonne espèce", Jean-François Trape in litt.). In former times, Günther (1864) considered *cliffordii* and *diadema* (as *Zamenis* auct.) distinct species due to "keeled ventral shields" and "small shields behind the frontals" in the latter, i.e., between the larger prefrontals and the frontal ("vertical"). Strauch (1873) only mentioned *Z. cliffordii*. Blanford (1881) assigned a Diadem snake from Dehbid (see Morphological Variation) with the latter condition but the ventrals "not distinctly angulate" to *Z. Cliffordi* [sic], noting that this taxon and *diadema* "are scarcely separable, as I have shown ('Eastern Persia', ii. p. 413)." Boettger (1888) distinguished these nominal species by the number of subcaudals (see Discussion: third paragraph).

Contrary to Schmidt (1939), Marx (1959) used trinominals for the *Spalerosophis diadema* complex including *S. atriceps* (see second paragraph above) and recognized *S. d. schirasianus* for populations from "the Zagros Mountains of western Iran eastward through southern Turkmen and Afghanistan into Pakistan and India, where it meets with *d. diadema*". The easternmost *schirasianus* are mapped in Baluchistan (Pakistan, then part of India) and, despite his blunder regarding the type locality of the nominate subspecies ("near Bombay"), not a single record of *S. diadema* from Mumbai or its farther vicinities appears; actually, the indicated distribution range of *Spalerosophis* spp. (*atriceps*, *diadema*) on the Indian Peninsula is restricted to areas north of a line from Sind (vicinity of Karachi) to Uttar Pradesh. Without taking into account the data of the lectotype of *Coluber diadema* Schlegel (see Early Descriptions), Marx (1959) diagnosed *cliffordii* (east to "extreme western Iran") by "less than 80" subcaudals versus at least 80 in more eastern subspecies (*diadema*, *schirasianus*), and "usually less than 100" in *schirasianus* vis-à-vis "usually 100 or more" in *diadema*.

Lanza (1964) discussed taxonomic implications with regard to *Coluber tyria* Linnaeus, 1758 re-introduced by Terentjev & Chernov (1936), a putative senior synonym of *C. diadema* Schlegel proposed to be rejected (see Mertens, 1940; Schätti *et al.*, 2009b), and drew attention to the exceedingly low number of subcaudals in the lectotype of *C. diadema* (see Discussion). Relying on Wall's (1914) comments regarding the type locality of *Spalerosophis d. diadema* and the distribution of the species in India, Minton (1966: 126, footnote) doubted the presence of *S. diadema* "near Bombay." Although body scale data of the type series point to a different origin ("the ventral and subcaudal counts given for the specimen are those of a snake of Iranian rather than Indian origin"), he recognized the "typical" morph of *S. d. diadema* sensu Marx (1959) from Pakistan and India ("western part of the United Provinces") and *S. d. schirasianus* from "Transcaspia [...] east to Tadzhikistan" and south to Baluchistan ("Quetta and western Las Bela").

Baig & Masroor (2008) came to the conclusion that *Periops parallelus schirasianus* Jan "is a junior synonym" of *Coluber diadema* Schlegel and applied the nominate species-group name to Diadem snake populations from Turkmenistan to Pakistan. Schätti *et al.* (2009a) were reluctant to accept this assumption and reminded the reader of the problematical distinction of subspecies in Southwest Iran and the taxonomic complication due to the supposed origin of the type series of *C. diadema* from that area.

In the following text, we recognize *Spalerosophis d. cliffordii* (Schlegel) from North Africa to Oman, Southeast Turkey, and Southwest Iran (Khuzestan) vis-à-vis *S. d. schirasianus* (Jan) from Turkmenistan to the Fergana Valley (Kyrgyzstan, Tadzhikistan) and south along the Zagros Range in Iran to western Pakistan (Baluchistan), and use 'eastern *diadema*' as a modus operandi for populations of Diadem snakes (*S. d. diadema* auct.) from east of approximately 67°E longitude in southern Pakistan to the southeastern escarpment of the Hindukush in Afghanistan and Chitral. Except for the remarks found in this section, we recommend the maps in Marx (1959), Lanza (1964), Gasperetti (1988), Trape & Mané (2006), and Baig & Masroor (2008) as basic references to grasp an idea of the distribution limits of the various taxa of the *S. diadema* group of species.

## Early descriptions

***Spalerosophis d. diadema*** (Schlegel, 1837)

["*Coluber*"] Russell, 1807: 34, Pl. XXX - "from Buchier" (type series see smallprint).
*Coluber diadema* Schlegel, 1837: 146 [vol. 1], 148 [2] - "pris dans les environs de Bombay" (see text).

The description of *Coluber diadema* and other new taxa including *C. cliffordii* in Schlegel (1837) is, or at least comprises, the text of the first volume ('Partie générale'). However, distinguished authorities (e.g., Duméril *et al.*, 1854; Günther, 1864; Boulenger, 1893; Marx, 1959) dealing with *diadema* or *cliffordii* (or both) cite only the second volume ('Partie descriptive'), an imprudence that also sneaked into Schätti *et al.* (2009b: 53). Opinions 1384 and 1856 (ICZN 1986, 1996), for instance, ruling on specific snake names (*Dendrophis* [*Dromophis*] *praeornata*, *Psammophis* [*Lycognathophis*] *seychellensis*) established by Schlegel (1837) attribute the original references to both volumes of the 'Essai sur la physionomie des serpens' ("vol. 1, p. 157, vol. 2, p. 236") or just "vol. 1 (Partie générale), p. 155", respectively. For the sake of clarity, we quote both and opted for the more detailed information regarding the origin of the type series as indicated in the 'Partie descriptive'.

Schlegel (1837, vol. 2) described the species upon Russell's (1807) illustration and text ("J'introduis cette belle espèce d'après la figure qu'en a donnée Russel [sic] II Pl. 30 p. 34") and erroneously reported the then syntypes from the vicinity of Mumbai. Russell (1807) averred that "[t]wo specimens in good preservation were received from Dr. Scott, of Bombay [Mumbai], sent to him from Buchier, by Mr. Bruce", i.e., Bushehr (Bushire) on the Gulf coast in Iran (Wall, 1914; Mertens, 1940; Minton, 1966; Wallach in Baig & Masroor, 2008).

The illustrated snake (Russell, 1807: Pl. XXX) is the smaller individual, as evidenced by the ventral scale count (220) and the fact that the drawing undoubtedly shows a male. Russell (1807) described that specimen adequately and Mertens (1940)

referred to it as the "Typus von *diadema*" or "*diadema*-Typus". This constitutes a lectotype designation (ICZN, 1999: Art. 74.5); the larger paralectotype ("Paratypoid") is most probably a female (see Morphological Variation, Tb. 2). No "types" of *Coluber diadema* Schlegel are listed in Boulenger's (1893) 'Catalogue'. Pending further investigations, the original material "may be lost" (Schätti *et al.*, 2009a).

Some herpetologists (e.g., Daudin, 1803a-b; Schlegel, 1837) who described new species upon Patrick Russell's 'Indian serpents' (1796, 1801-1809) relied on the text and plates in the various sections of this pictorial atlas. Although many mentions of "Russell" in Boulenger's (1893-1896) synonymies are not documented by material, it would be wrong to conclude that they were established without access to specimens; some were perhaps presented by Russell himself or received in the first half of the 19$^{th}$ century, as in the case of *Coluber* [*Dryocalamus*] *nympha* Daudin, 1803a (Kucharzewski & Tillack, 2008); others were obtained and incorporated into the collections of the former 'British Museum (Natural History)' at the very end of Boulenger's professional career as, for instance, the holotype of *Enhydrina schistosa* Daudin, 1803b donated by the Royal College of Surgeons in 1921 (see Wall, 1909); this species is based on Russell's (1801: p. 11, Pl. X) 'hoogli pattee' (fide Smith, 1926). Further specimens may be concealed among the "collection of Indian Reptiles made by Dr. Patrick Russell, containing the types of the species described by him in [...] 1796" and stated to be "preserved as skins" (Boulenger, 1906: 518, 530, see below). Skins mounted on paper or parchment and apparently received in 1837 ("purchased from Mr Sotherby") are registered as from the "Burmese Empire"; unfortunately, they are without a more precise reference, in particular any hint to Russell (Colin McCarthy in litt.). To judge from notes on these sheets, it seems that John Edward Gray was intending to include them in his inventory of snakes, an idea later abandoned perhaps because he decided that the source was too tenuous; however, preserved complete specimens ("In spirits") are listed (Gray, 1849: e.g., pp. 24, 30, 48). Similarly, Günther (1858, 1864) wholly ignored these skins, and Smith's (1943: 531-532) identification list of Russell's snakes does not assign the illustrations to actual holdings including preserved specimens at all. Boulenger (1906: 528) reported further "skins of Indian Snakes [...] including the original examples described by this pioneer in Indian Herpetology" purchased in 1904, roughly one hundred years after Russell's death in 1805. Compelling evidence linking nearly one hundred catalogued items (BMNH 1904.7.27.1-97) with the 'Indian serpents' is found in the register, i.e., an entry in Boulenger's handwriting dating from July 1904 documenting "snake-skins from India, prepared by Dr Patrick Russell" purchased from a descendent; although clearly involved personally, George Albert Boulenger nevertheless did not make any attempt to retrieve the plates of the 'Indian serpents'. By all means, no serious efforts to locate material first described and figured in the 'Indian serpents' were made in modern times. This recently resulted in the designation of a neotype for *Coluber tristis* Daudin, 1803a by Rooijen & Vogel (2008) who believed Russell's specimens to be stored in Paris (MNHN), the working place of François Marie Daudin ("Daudin did not deposit a type-specimen in a collection as was usual at that time").

There "appear an unusual row of small laminae" behind the "sub-triangular" prefrontals which are larger than the internasals (Russell, 1807). The portrayal shows three scales separating the larger prefrontals from the frontal and two (one on each side) additional supranumeral scutes in front of the supraoculars; on the left, there are three (two lower, one upper) loreals and two or three secondary labials. Russell (1807) reported 220 ventrals and 61 "Squamae Subcaudales" for the lectotype (see Discussion) and 238 ventrals ("abdominal scuta") in the paralectotype. The dorsals are "oval, smooth, and every where very small in size" but they are keeled ("carénées", see footnote 1) according to Schlegel (1837).

The parietals are "marked with four darkish dots" (Russell, 1807). The dorsum is "cineritious, with large darkish ragged spots along the ridge of the back, while others smaller and more faint are scattered on the sides. The abdomen and under part of tail are uniformly white without spots." Schlegel (1837) described the dorsal coloration as

brown like earth ("brun de terre" [vol. 1], "la teinte d'un brun couleur de terre" [2]) and mentioned the transverse dark band between the eyes.

***Spalerosophis diadema cliffordii*** (Schlegel, 1837)

*Coluber guttatus* Forskål, 1775 [non *C. guttatus* Linnaeus, 1766]: 14 - "Ad Káhiram" [vicinity of Cairo] (supposed holotype not located, see Schätti *et al.*, 2009b).
*Coluber cahirinus* Gmelin, 1789: 1115 (nomen novum for *C. guttatus* Forskål, 1775).
["Couleuvre aux raies parallèles"] Geoffroy Saint-Hilaire, 1827: 147, Pl. 8.1 ("Égypte": incl. MNHN 3572, 3574).
*Col.*[*uber*] *versicolor* "Opp.[el]" Wagler, 1830 [non *C. versicolor* Razoumowsky, 1789, non *C. versicolor* Merrem, 1820]: 189, footnote 5 - origin not indicated (see second paragraph).
*Col.*[*uber*] *Geoffroyii* [sic] Gray, 1831: 87 - ["Egypt"] ("Coulévre [sic] aux raies paralleles [sic], Geoff. Rept. Egypt").
*Coluber cliffordii* Schlegel, 1837: 148 [vol. 1], 163 [2], Pl. VI.13-14 - "États barbaresques" [Tripoli, Libya] (incl. RMNH 467A-B, see text, Material, and *Spalerosophis d. diadema*: first paragraph).
*Periops pyramidum* Gistel, 1848: 100 - ["Egypt"] ("Geoffr. Descript. de l'Egypte etc. 8. f. 1").
*Periops parallelus* Duméril, Bibron & Duméril, 1854: 678 - "originaire d'Egypte" [Egypt, Tunisia (Sfax) and "sur les bords de la mer Rouge"] (incl. MNHN 3571-3574 and 1999.8250 [formerly 3574A]).

*Coluber cahirinus* Gmelin (new replacement name for the primary homonym *C. guttatus* Forskål) and *C. geoffroyii* Gray are nomina oblita (Schätti *et al.*, 2009b). The junior synonym *Periops pyramidum* Gistel, valid by indication (ICZN, 1999: Art. 12.1-2), is an overlooked name re-discovered by Mertens (1921). As far as we are aware, and apart from Sherborn's (1929) 'Index animalium', it was only used by Gistel (1848, 1850); Gistel (1868) did not mention this specific name.

*Coluber versicolor* Wagler, established upon a label name coined by Nikolaus Michael Oppel in the "Pariser Museum", is preoccupied; this name was rarely cited, but considered valid, in literature (e.g., Boettger, 1885, 1888). Although irrelevant for technical purposes, we take this opportunity to emphasize that the oldest catalogue of the herpetological collections of the MNHN dating from 1864 [manuscript] lists ten specimens of *Spalerosophis diadema* (as *Zamenis parallelus* [MNHN 3571] and *Z. diadema*); apart from the type series of *Periops parallelus* Duméril, Bibron & Duméril, these are MNHN 1904.559 and 1904.560a-c collected by Jacques de Morgan in "Perse", which arrived at the museum at the beginning of the last century. The supposition that *C. versicolor* Wagler hailed from northern Africa (Boettger, 1885) is entirely based on Wagler's (1830) indication of the distribution of *Periops* spp. auct. ("Europa, Africa") to which *versicolor* was assigned. There is no trace of, nor hint to, Oppel's specimen, and the matter is open to speculation, e.g., that it may have been among the series available to Geoffroy Saint-Hilaire (1827). Gistel (1848) introduced his name as "*Periops pyramidum* (Gistl)" [sic]. As a matter of fact, some publications by this author were published under this spelling as well as the pseudonym 'G. Tilesius' (Pieper, 1996). Due to the original citation, Mertens (1921) concluded that Johannes Nepomuk F. X. Gistel had published the specific name earlier ("muß [...] schon früher beschrieben worden sein"); however, we do not know any reference of *pyramidum* Gistel prior to 1848. Sherborn's (1929) entries give that author's name as "J. Gistl"; 1847 as year of publication of the 'Naturgeschichte des Thierreichs' ("Handb. Naturges. 1850 [1847]") is in error.

*Coluber cliffordii* Schlegel was described on the basis of an unknown number of specimens received from Clifford Cocq van Breugel, the Dutch Consul at Tripoli, Libya. This place is generally considered the type locality (e.g., Mertens, 1940; Marx, 1959). Kramer & Schnurrenberger (1963) located two of Schlegel's (1837) females in the Leiden collection ("RNHL [sic] 467", Fig. 1) and, following a suggestion by the then curator ("Wir schliessen uns dem Vorschlag von Herrn Prof. Brongersma an"), conferred lectotype status to the smaller specimen 'b', i.e., RMNH 467A (see Material), which was carelessly supposed to be ("es ist anzunehmen") the one figured in Schlegel (1837: Pl. VI.13-14). This action was apparently taken in ignorance of Mertens (1940), whose quotation of the actually illustrated individual as the "Typus von *Coluber cliffordii* Schlegel" meets the provision of Art. 74.5 of the 'Code' (ICZN, 1999) and qualifies as a lectotype designation. We do not have any information on its whereabouts.

The two RMNH specimens of Schlegel's (1837) original series are paralectotypes. None of them corresponds to the lectotype with just the nine ordinary colubrine dorsal head shields, which is definitely a highly uncommon condition for *Spalerosophis* spp. RMNH 467A shows four prefrontals of which three are in contact with the frontal; RMNH 467B has two large prefrontals; the left is separated from the frontal by a small narrow supranumeral scute (see Terminology). Based on an examination by Leo D. Brongersma, Kramer & Schnurrenberger (1963) erroneously noted a scale separating the frontal from the first periocular ("preocular") on the left side of both paralectotypes, and partial separation on the right side of RMNH 467A ('b': "Fr[ontal] rechts teilweise, links vollständig durch ein Schildchen vom Pro [preocular] getrennt"). In reality, both specimens have the first periocular in contact with the frontal on both sides.

Schlegel (1837, vol. 2) mentioned Geoffroy Saint-Hilaire's (1827) illustration as an early reference of *Coluber cliffordii* (see also Schätti *et al.*, 2009b: footnote 2). According to the 'Description de l'Égypte', the figured specimen (MNHN 3574, see smallprint and text below) measures approximately 1083 mm total length ("deux pieds huit pouces" snout-vent length and "sept pouces" for the tail). The morphological description of the "Couleuvre aux raies parallèles", however, is based on a different specimen (MNHN 3572), a female with 244 ventrals and 71 paired subcaudals (verified as 241 plus three preventrals and 72+? subcaudals; extreme tip of tail missing) measuring "deux pieds sept pouces et demi" (approx. 874 mm) total length.

The spelling of the French vernacular name is not consistent throughout the 'Description de l'Égypte'; the plural ("[Couleuvre] aux [raies parallèles]") appears in the caption of the description and illustration (Geoffroy Saint-Hilaire, 1827: 147, Pl. 8.1) as well as on page 150 (last line) but the singular ("à") is used on the same page (penultimate paragraph) and twice on the next. Schlegel (1837) and Duméril *et al.* (1854) reported Geoffroy Saint-Hilaire's (1827) account on this colubrid as on page 67 or 89, respectively (see Schätti *et al.*, 2009b: footnote 4). The figured male (MNHN 3574) was obtained by Antoine Barthélémy Clot. This physician became chief surgeon to the Egyptian viceroy Muhammad Ali Pasha ('Mehmed Ali') who bestowed on Clot the title of 'Bey' in 1832.

*Periops parallelus* Duméril, Bibron & Duméril is based on seven syntypes, but only five are catalogued: MNHN 3572 with a total length of 853 (710 + 143 mm) received from Isisore Geoffroy Saint-Hilaire as well as three fine specimens ("beaux

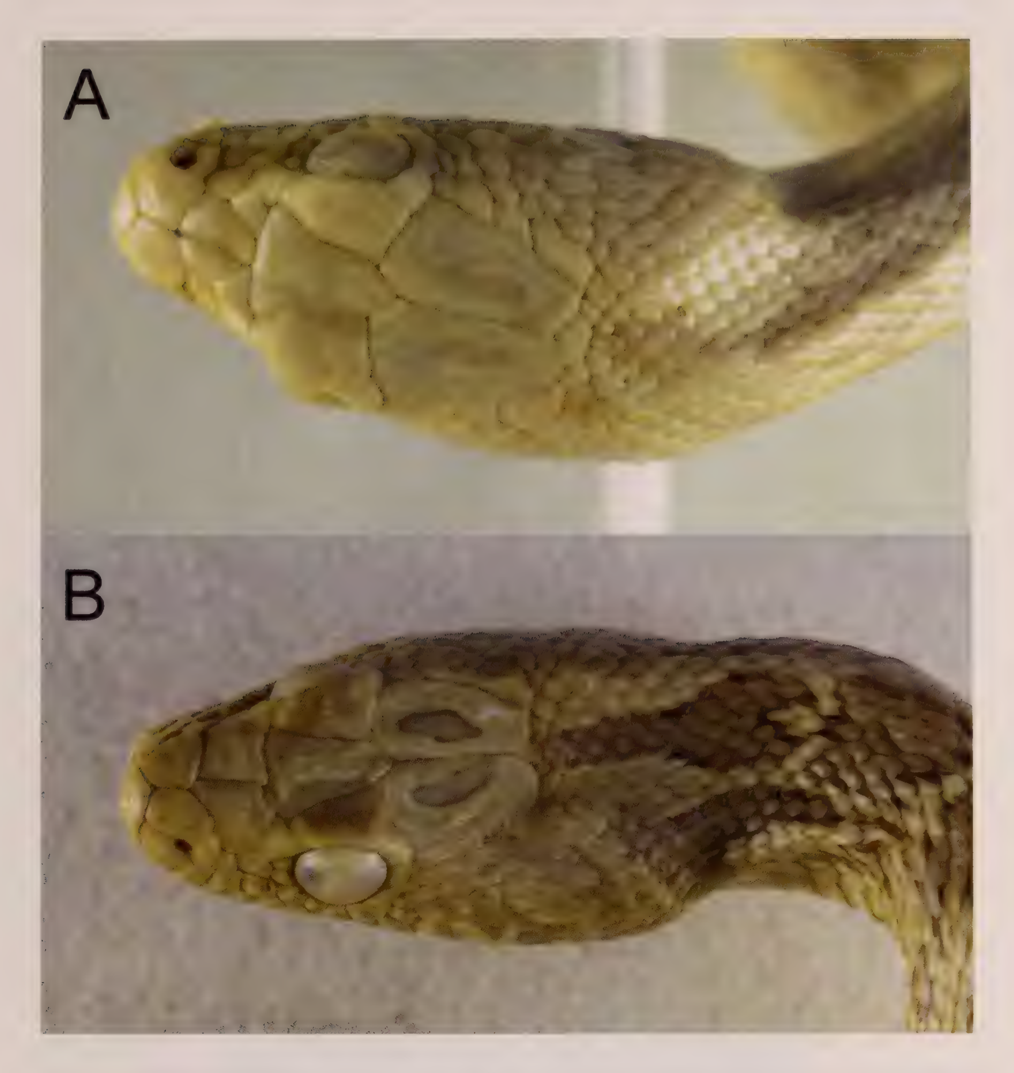



FIG. 1
Dorsolateral head view of paralectotypes of *Coluber cliffordii* Schlegel, 1837: RMNH 467A (A) and 467B (B) from "Tripoli", Libya. Not to scale. Photographs by Eelco Kruidenier.

sujets") presented by 'Clot-Bey' (MNHN 3573: 1'362 [1'190 + 172] mm; 3574: 1'070 [872 + 198] mm; 1999.8250: 1'314 [1'090 + 224] mm), all from unspecified places in Egypt and without date of acquisition, and a subadult (MNHN 3571, leg. "Spina 1853") with 418 (347 + 71) mm from Sfax, Tunisia. Two (adult, juvenile) syntypes found in shipments of Paul-Émile Botta from the Red Sea area ("sur les bords de la mer Rouge"), possibly originating from the Arabian Peninsula, do not appear in the MNHN file register; actually, they were never incorporated into the herpetological collection (according to the 1864 unpublished catalogue, see second paragraph above), but might be located in another museum.

Strangely, Duméril *et al.* (1854) cited *Coluber Cliffordii* [sic] in their list of synonyms and alluded to Schlegel (1837) in the text, as did Jan (1863) who used the junior synonym *Periops parallelus* as the valid name for the species. Furthermore, Jan (1863, 1865) erroneously considered Geoffroy Saint-Hilaire (1827) to be the author of *P. parallelus*, probably as a consequence of ambiguous remarks in the 'Erpétologie générale'. The deceptive notion of "type" in Duméril *et al.* (1854) clearly refers to Geoffroy Saint-Hilaire's (1827) oeuvre ("M. Geoffroy a déposé dans le Musée l'exemplaire qui lui [him (!)] a servi de type"), i.e., the "Couleuvre aux raies parallèles", and does not constitute a holotype designation in the sense of Art. 73.1.1 (ICZN, 1999).

According to Duméril *et al.* (1854: 678, footnote), Botta's juvenile syntype of *Periops parallelus* and "le type de M. Geoffroy" (MNHN 3572) have only nine dorsal head shields; however, the latter shows a small supranumeral scute between the left central prefrontal, the upper loreal, and the frontal. MNHN 3573 has a total of six prefrontals comprising a small azygous scale on the right; the remaining syntypes including Botta's larger specimen possess a total of four or five (MNHN 3571) scales in the prefrontal region (Fig. 2, see Terminology). Form, size, and position of the two supranumeral scutes of MNHN 3574 figured in Geoffroy Saint-Hilaire (1827: Pl. 8.1') are not accurate; there is, for instance, no separation of the first periocular from the frontal (Fig. 2D). In general, many of the illustrations and drawings in the 'Description de l'Égypte' are not very precise (Roger Bour, pers. comm.), and certainly not reliable when it comes to attribute them to museum specimens.

Schlegel's (1837: Pl. IV.14) figure of the unlocated lectotype of *Coluber cliffordii* shows ten supralabials, three secondary labials, three (two lower, one upper) loreals, eleven periocular, and five temporals in the first and second row, respectively. Kramer & Schnurrenberger (1963) reported ten (right) to eleven (left) and eleven (left) to twelve supralabials, six and three to four "loreals" (including secondary labials), and ten or eleven periocular in RMNH 467A and 467B, respectively (see Material). RMNH 467A has ten supralabials, three secondary labials, and three (two lower, one upper) loreals (data from photographs, supralabials only verified on left side); RMNH 467B (only left side counts) has one secondary labial, two loreals (the prefrontal extending far downwards laterally), and twelve supralabials of which the seventh enters the eye, a very unusual condition within the genus *Spalerosophis* Jan (e.g., Marx, 1959; Schätti *et al.*, 2009a).

The syntypes of *Periops parallelus* have ten (juveniles) to twelve (adults) supralabials and three (two lower, one upper) loreals; reported "anomalies" in the upper labial region ("se retrouvent [...] pour les plaques sus-labiales", Duméril *et al.*, 1854: 678, footnote) refer to the occurrence of usually two (one to three) secondary labials (see Geoffroy Saint-Hilaire, 1827: Pl. 8.1). The number of periocular in the type series of *P. parallelus* ranges from 9 to 11.

Schlegel's (1837) counts for ventrals and subcaudals in *Coluber cliffordii* are "236 + 84" (vol. 1) or 230-240 and 66-90 (vol. 2), respectively; the minimum for subcaudals may stem from RMNH 467B and the maximum of 90 (vol. 2) is most likely erroneous. Kramer & Schnurrenberger (1963) noted 229 ventrals and 72 paired subcaudals in the smaller extant paralectotype (RMNH 467A) and 232 ventrals (67 "+?" subcaudals) in the larger. Duméril *et al.* (1854) gave 223-241 ventrals and 70-74 subcaudals for *Periops parallelus*; one male (MNHN 3574) has only 219 ventrals, and at least MNHN 3572 (72+?), 3574 (75+?), and 1999.8250 (72+?) lack the extreme tip of tail.




FIG. 2

Dorsal head view of syntypes of *Periops parallelus* Duméril, Bibron & Duméril, 1854: MNHN 3571 (A) from Sfax, Tunisia, MNHN 3572 (B), 3573 (C), and 3574 (D) from "Égypt". Not to scale.

The dorsal scales are small ("peu grandes"), lanceolate, and with strong obtuse keels ("forte carène émoussée"); probably, Schlegel's (1837, vol. 2) count of longitudinal rows (23 msr) is not the maximum at midbody (see Terminology). Brongersma

found 25 msr in RMNH 467A-B (Kramer & Schnurrenberger, 1963). Duméril *et al.* (1854) reported higher (29-31 msr) counts and noted that the median dorsal scales are more pointed and longer than those of the lateral rows, from which the former also differ in possessing obtuse keels ("à carènes peu saillantes"); this condition is more manifest towards midbody ("d'autant plus apparente, qu'on examine les écailles plus loin de la tête") and better visible in juveniles.

The dorsum is greyish brown with three series of brown spots along the trunk; those of the median row are largest and of variable shape (squarish, oval or confluent and arranged in longitudinal streaks). The dorsal markings are pale brown ("d'un brun livide") according to Schlegel (1837, vol. 2) but very distinct ("très-prononcées") following Duméril *et al.* (1854).

***Spalerosophis diadema schirasianus*** (Jan, 1863)

*P.*[*eriops*] *parallelus* "(Geoffr. St Hil.) Dum. e Bibr." var. *schirasiana* Jan, 1863: 60 - "Schiraz, Persia" (MSNM, see text and *Spalerosophis diadema cliffordii*: second smallprint).

*P.*[*eriops*] *parallellus* [sic] "Geoff. var" [sic] *Schiraziana* [sic]. - Jan, 1865: 356 (incorrect subsequent spelling).

*Periops parallelus* var. *schirazana* [sic]. - Sordelli in Jan & Sordelli, 1867: inside of cover ['Index des planches'], Pl. II ("Schiraz, Perse").

Anderson & Leviton (1969) regarded *Periops parallelus* var. *schirasiana* Jan, 1863 (under *Sphalerosophis* [sic]) as not available (nomen nudum); they thought Jan's (1865) text in the 'viaggio in Persia' to be the "original description" and *schiraziana* [sic] with the "type locality Persia" the correct name of the taxon ("the provenance of the [sic] type specimen" is further commented in Leviton *et al.*, 1992). The feminine form (Jan, 1863, 1865) is in accordance with the gender of the Latin word 'varietas', and the correct subspecific name is *schirasianus*.

As is generally the case with the 'Elenco' (Jan, 1863), collection data (origin and location: "M.", i.e., MSNM) are brief and the diagnosis of *Periops parallelus schirasianus* Jan, which comes along with the one for *P. parallelus* Duméril, Bibron & Duméril, is concise: four or more prefrontals, twelve supralabials, none in contact with orbit ("Prefrontali più di 4; sopralabiali 12. Nessuno dei quali a contatto dell'occhio"). We understand that this meets the provision of Art. 12.1 (ICZN, 1999: the "new name [...] must be accompanied by a description or a definition of the taxon that it denotes") and renders Jan's (1863) name available. The careless handling of orthography in those times is exemplified by Jan's (1865) *P. parallellus* [sic] or Jan & Sordelli's (1867) "*schirazana*", a lapsus probably penned by the illustrator Ferdinando Sordelli (Schätti *et al.*, 2009a). We do not concur with Anderson & Leviton (1969) that "var. *schirasiana* Jan, 1863, Elenco Sist. delgi [sic] Ofidi" was a nomen nudum, and there is no reason to apply Art. 33.3.1 (ICZN, 1999: "when an incorrect subsequent spelling is in prevailing usage and is attributed to the publication of the original spelling", it "is deemed to be a correct original spelling") because the adscription to Jan (1863) is not given.

A similar case is *Zamenis* [*Platyceps*] *rhodorachis* Jan, 1863 also described from "Schiraz". Boulenger's (1893) 'Catalogue', to cite a milestone work, gives the 'viaggio in Persia' (Jan, 1865) as the original reference. However, the 'Elenco' provides an unambiguous diagnosis of this species (number of supralabials and midbody dorsal scale rows as well as, by implication, the peculiar dorsal colour pattern of the typical morph consisting of a red mid-dorsal stripe) and *rhodorachis* Jan, 1863 is definitely no nomen nudum, nor dubious (something never

claimed to be the case by any zoologist, to make it clear). We conclude that this name and *Periops parallelus schirasianus* were almost universally associated with Jan (1865) due to ignorance or negligence (Schätti *et al.*, 2010). A further instructive example to illustrate the confusion surrounding the author, year of publication, and spelling of *Spalerosophis diadema schirasianus* is found in Strauch's (1873: 106, 109) 'Schlangen des Russischen Reichs' where "1867. [...] Jan. Iconographie des Ophidiens Livr. XX, pl. II" is quoted in the synonymy of Z. *cliffordii* although "Jan. Elenco [...] p. 60" and "Filippi. Viaggio [...] p. 356" are cited in two footnotes regarding its distribution; the "Varietas *schirazana*" [sic] "Jan" appears in the text.

Jan (1865) stated that he had caught sight of numerous individuals ("molti exemplari da me veduti") but this may not necessarily have been the case two years earlier. By all means, there is no evidence of how many specimens Jan (1863) had seen or examined when describing the taxon, and any type material of *Periops parallelus schirasianus* formerly hold in the Milan collection (MSNM), possibly including one of the two snakes (see below) figured in Jan & Sordelli (1867: Pl. II), is lost (Scali, 1995).

Based on an original label ("Originaletikette") reading "Teheran, Nordpersien, 1863. Coll. Doria. No. 37. *Periops parallelus* Geoff. var. *shiraziana* [sic] Jan. Tipo. juvenil. Determ. Jan", Kramer & Schnurrenberger (1963) designated a male ("Arbeitsnummer [SK] 3323") of the MSNG 30350-51 series ("Syntypenreihe", five specimens) from the vicinity of Teheran as the lectotype of *P. p. schirasianus* Jan. This action neglects Recommendation 74E ('Verification of locality') of the 'Code' (ICZN, 1999).

Kramer & Schnurrenberger (1963) listed five tag numbers (SK 3322-3326) for six individuals. SK "3326" from the "Krasnovodsky Plateau" (Turkmenistan) is SK 1126, i.e., MHNG 1375.61. According to Giuliano Doria (in litt.), the actual SK 3326 (MHNG 1375.62) belonged to one out of two specimens registered under MSNG 30351 (30350 following Kramer & Schnurrenberger, 1963); reversely, SK 3323 is part of the MSNG 30350 series (3 specimens), not 30351. In the chapter dealing with *Sphalerosophis* [sic] *diadema cliffordi* [sic], Kramer & Schnurrenberger (1963: 526) used the term "*schirazianus*-Rasse", but in a comment regarding the type series of *Zamenis rhodorachis* Jan and the usage of 'type' by Giorgio (Georg) Jan in the sense of syntypes (",,Tipo" ist hier mit Syntypus und nicht etwa mit Holotypus zu übersetzen"), the taxon is named *S. d. shiraziana* [sic], i.e., the specific spelling found on the label of the putative syntype series.

Contrary to other members of the 1862 Italian mission to "Persia" (e.g., Filippo De Filippi, Michele Lessona) who returned that same year (except the diplomatic staff headed by Marcello Cerutti), Marquis Giacomo Doria spent wintertime in southern Iran (e.g., De Filippi, 1862, 1863; Branca, 1869). He collected natural history items along the way (e.g., around Esfahan [Isfahan], Hamadan, Shiraz, and Yazd) to the Persian Gulf and back to the Teheran area including, for instance, "Veramin" (Varamin, 35°20'N 51°39'E) in spring 1863 (Blanford, 1876: 144, 288). This expedition to as far as the Strait of Hormoz (Bandar Abbas) also passed through Lorestan as evidenced by the lectotype of *Spalerosophis microlepis* Jan. Although we were unable to trace the itinerary of Doria's homeward journey and determine the month of his arrival in Italy, this time schedule casts legitimate doubts on the likelihood that his herpetological specimens found their way into the 'Elenco' (Jan, 1863). Furthermore, Capocaccia's (1961) catalogue of the Genoa type collection does not cite *Periops parallelus schira-*

*sianus*, strengthening the case against the taxonomic status of MSNG 30350-51 as argued by Kramer & Schnurrenberger (1963), and we do not consider Diadem snakes from "Teheran" collected by G. Doria to belong to the type series of *P. p. schirasianus*.

Kramer & Schnurrenberger (1963) identified "SK 3323" with the smaller specimen illustrated in Jan & Sordelli (1867: Pl. II.B) but their unnumbered table on page 528 gives a snout-vent length of 1'100 mm for "MSNC [sic] 3323", actually the largest size for any Diadem snake of the MSNG series (coll. Doria); thirteen supralabials are tabulated. However, the 'Iconographie générale' depicts a halfgrown specimen from "Schiraz" (instead of "Teheran") with twelve supralabials on the left side (eleven of regular shape plus one triangular scale wedged in between the tenth and last). Contrary to the original description ("sopralabiali 12"), the larger snake (Jan & Sordelli, 1867: Pl. II.A) exhibits only ten supralabials on both sides and it remains unclear which specimen figured in the 'Iconographie générale' is, or was, deposited in the MSNG ("collection Doria, à Gènes").

## Morphological Variation

The analysis of dorsal and lateral head scales as well as ventral, subcaudal, and msr counts of *Spalerosophis diadema* ssp. compiled for this study resulted in the data shown in Tbs 1-2.

Table 1. Number of scales in prefrontal region, supralabials, and periocular of *Spalerosophis diadema* ssp. from southern Iraq to Pakistan (see text, Material and Methods). Mean and number of specimens in parenthesis. *Coluber diadema* Schlegel: lectotype fide Russell (1807); *S. d. cliffordii* (Schlegel): Schmidt (1930), Corkill (1932), Hellmich (1959), Marx (1959), Afrasiab & Ali (1989); *S. d. schirasianus* (Jan): Jan (1863), Jan & Sordelli (1867), Blanford (1876, 1881), Boettger (1888), Werner (1895), Zugmayer (1905), Lantz (1918), Werner (1936), Mertens (1940), Schmidt (1955), Hellmich (1959), Kramer & Schnurrenberger (1963), Anderson & Leviton (1969); 'eastern *diadema*' (*S. d. diadema* auct.): Günther (1864), Khan (1986), Baig & Masroor (2008).

| Taxon | prefrontals | supralabials | periocular |
|---|---|---|---|
| *Coluber diadema* | 7 (1) | – | – |
| *S. diadema cliffordii* | 4-6 (5.0, 3) | 10-12 (11.6, 16) | 6-11 (8.6, 18) |
| *S. d. schirasianus* | 4-7 (5.0, 15) | 10-14 (11.9, 23) | 7-11 (8.9, 21) |
| 'eastern *diadema*' | 5-7 (6.0, 5) | 10-14 (12.2, 5) | 7-8 (7.8, 4) |

Hellmich (1959) reported partial contact of the larger prefrontals with the frontal in *Spalerosophis diadema cliffordii* from Khuzestan (see Discussion). *S. d. schirasianus* usually shows five prefrontals including a transverse row of three smaller scales separating the larger anterior scales from the frontal (e.g., Jan & Sordelli, 1867: Pl. II; Blanford, 1876, 1881; Boettger, 1888; Zugmayer, 1905; Werner, 1936; Mertens, 1940). A "large snake" from Iran ("Persia") has "the central supplementary shield [...] irregularly divided" (Blanford, 1876). Werner (1895) observed five small scales behind the two regular prefrontals ("hinter den gut entwickelten Praefrontalen fünf kleinere Schildchen") in an incomplete specimen (head only) from Kerman Province. Mertens (1940) mentioned two Diadem snakes which appear to have just one or two small supranumeral scutes, i.e., one (the right) of the larger prefrontals in contact with the frontal, and in two *S. diadema* from near Kerman and the vicinity of Shiraz (Dehbid)

"the post-frontals [prefrontals] are in contact with the vertical [frontal]" (Blanford, 1876, 1881). Counting the "frontonasals" (see Terminology), Baig & Masroor's (2008) values for prefrontals (5-6) of 'eastern *diadema*' agree with an indication in Khan (1986: "six"). Günther (1864) reported "a transverse series of four small shields" (actually, there is an additional granule in the illustrated specimen) between the larger prefrontals ("anterior frontals") and the frontal ("vertical") in Diadem snakes from 'British India' (see Discussion).

Summary data for the number of supralabials are 10-12 (mean 11.1, n=9: Marx, 1959; see also Khalaf, 1960) in *Spalerosophis diadema cliffordii*, 12-14 (12.4, 12: Schmidt, 1939; Marx, 1959) for *S. d. schirasianus*, and 10-13 (11.8, 6: Marx, 1959) in 'eastern *diadema*'. As few as six perioculars in *S. d. cliffordii* from Iraq (Marx, 1959) is most probably based on an anomaly in FMNH 11067 collected at Kish (32°32'N 44°42'E); this specimen shows six on one side (left) but nine on the other (Schmidt, 1930). Khalaf (1960) gave seven to nine scales around the eye for Iraqi specimens. The single count of eleven perioculars in *d. cliffordii* is from USNM 121592 (Ahvaz, Iran). Marx's (1959) condensed compilation for *d. schirasianus* from the Teheran area notes 7-11 (mean 9.0, n=12) perioculars but Schmidt (1939) gave "six to 10" for this series. Zugmayer (1905) found eleven scales in a specimen from Chardzhev ("Tschardschuj") on the Amu Darja in eastern Turkmenistan, and eight to eleven perioculars are observed in Pakistani *schirasianus* (Minton, 1966). Data for 'eastern *diadema*' (Tb. 1) are from Günther (1864: Pl. XXI.G) and Baig & Masroor (2008) but up to eleven perioculars are reported (see Discussion).

Populations of *Spalerosophis diadema cliffordii* from southern Iraq and Khuzestan differ from *S. d. schirasianus* and 'eastern *diadema*' in their low number of subcaudals (less than 75 in the area under consideration). Diadem snakes from Turkmenistan to Pakistan have more ventrals than *d. cliffordii*, and 'eastern *diadema*' show more subcaudals and a higher mean for ventrals vis-à-vis *d. schirasianus* (Tb. 2). The latter has fewer msr than the western and eastern subspecies, and the maximum (31) is attained by a single record (♀) from Fars (Boulenger, 1893); our mean (27.3) closely agrees with condensed data in Schmidt (1939) and Marx (1959), i.e., 27.0 and 27.2, respectively (genders combined).

Boulenger (1893: letter v) classified a Diadem snake from "Persia" with 230 ventrals as a female; it is grouped as 'unsexed' due to doubts (Tb. 2). Counts of most female *Spalerosophis diadema schirasianus* do not exceed 245; one from Dehbid (30°38'N 53°13'E, Fars) has 248 ventrals (Boulenger, 1893: letter w, collector not indicated), another from Birjand in Khorasan has 252 (Mertens, 1956).

Potential intergrades between *Spalerosophis diadema schirasianus* and 'eastern *diadema*' from "Afghanistan" and Baluchistan (Pakistan, see Discussion) are not included in the analysis (Tbs 1-2). Sexual dimorphism is found in the means of ventrals of all three subspecies; the maximum (238) reported by Marx (1959) for male *S. d. schirasianus* (237 fide Schmidt, 1939) requires confirmation. The same count (238), possibly also comprising the preventrals, is found in the paralectotype of *Coluber diadema* Schlegel (fide Russell, 1807) considered to be a female. *S. d. schirasianus* and 'eastern *diadema*' hardly show any significant difference in subcaudals between males

TABLE 2. Gender, number of ventral, subcaudal, and midbody dorsal scale rows of *Spalerosophis diadema* ssp. from southern Iraq to Pakistan (see text, Material and Methods). Mean and sample size in parenthesis. *Coluber diadema* Schlegel: lectotype (♂) and paralectotype (probably ♀) fide Russell (1807); *S. d. cliffordii* (Schlegel): Corkill (1932), Hellmich (1959), Marx (1959) [includes data of Schmidt, 1930], Afrasiab & Ali (1989); *S. d. schirasianus* (Jan): Strauch (1873), Blanford (1876), Boettger (1888), Boulenger (1893), Zugmayer (1905), Lantz (1918), Werner (1936), Mertens (1940), Schmidt (1955), Mertens (1956), Hellmich (1959), Marx (1959) [material of Schmidt, 1939], Kramer & Schnurrenberger (1963), Minton (1966) [Las Bela (Ormara) and Quetta area, n=4], Anderson & Leviton (1969), Mertens (1969) [SMF 57340: Jiwani]; 'eastern *diadema*' (*S. d. diadema* auct.): Günther (1864), Boulenger (1893), Wall (1911b), Marx (1959), Minton (1966) [Rawalpindi and Swat (Udigram), n=3], Mertens (1969) [SMF 50454, 57337, 63044: Quetta area (Urak) and vic. Mansehra], Khan (1986), Baig & Masroor (2008).

| Taxon | gender | ventrals | subcaudals | dorsals (msr) |
|---|---|---|---|---|
| *Coluber diadema* | ♂ | 220 | 61 | - |
| | ♀ (?) | 238 | - | |
| *S. diadema cliffordii* | ♂♂ | 214-228 (218.2, 11) | 70-74 (72.1, 10) | 29-33 (30.7, 23) |
| | ♀♀ | 223-236 (227.9, 8) | 64-73 (67.3, 7) | |
| | unsexed | 220-224 (222.3, 4) | 65-72 (69.0, 5) | |
| *S. d. schirasianus* | ♂♂ | 214-238 (?) (226.2, 32) | 76-93 (84.6, 28) | 25-29 (rarely 31) (27.3, 40) |
| | ♀♀ | 234-252 (241.6, 18) | 77-87 (82.8, 16) | |
| | unsexed | 230-242 (236.0, 6) | 80-90 (85.0, 9) | |
| 'eastern *diadema*' | ♂♂ | 233-245 (240.1, 16) | 101-110 (105.6, 11) | 29-31 (29.5, 34) |
| | ♀♀ | 244-255 (249.5, 19) | 101-108 (104,6, 12) | |
| | unsexed | 244-246 (245.0, 2) | 95-109 (102.0, 2) | |

and females. The number of midbody dorsal scale rows (msr) is virtually identical for both genders of all three subspecies.

## DISCUSSION

The somewhat negligent description of *Coluber diadema* Schlegel reflects the way how that account came about, i.e., in the absence of physical evidence. Apart from ventral and subcaudals counts, the description is devoid of scale data. In particular, the complete separation of the larger prefrontals from the frontal is not mentioned, and it remains mysterious how Schlegel (1837) incorrectly established the condition of the dorsal scales (pretended to be keeled, see footnote 1). This and the dorsal colour pattern including head markings were considered diagnostic for the species ("peuvent servir de caractère à l'espèce").

Schlegel (1837, vol. 2) and Duméril *et al.* (1854) emphasized that cephalic scale features separate *Coluber cliffordii* and *Periops parallelus*, respectively, from all (!) other colubrines ("peut servir de guide pour la reconnaître parmi toutes les autres Couleuvres"; "Cette espèce [...] peut être distinguée de toutes les Couleuvres"). However, contrary to Schlegel (1837) who merely referred to lateral head scales (see Early Descriptions), the assertion of Duméril *et al.* (1854: "Ces différentes anomalies [...] constituent un caractère particulier de cette espèce") explicitly includes the incidence of usually two supranumeral scutes on the pileus ("le plus souvent, onze plaques sus-céphaliques") as formerly averred by Geoffroy Saint-Hilaire (1827: "plaques du dessus de la tête présentent quelques differences que la figure 1' exprime parfaitement").

Schlegel (1837) deemed small irregular head scales ("tête [...] revêtue de petites écailles de forme irrégulière") an exclusive character state of *Coluber cliffordii* ("propre à l'espèce") but only secondary labials and loreals, perioculars, and temporals are mentioned in the text ("[...] occupent la place des lames du frein, des oculaires et des temporales") and depicted in the illustration. In any event, contemporary authors followed the far more meticulous and reliable description of the junior synonym *Periops parallelus* Duméril, Bibron & Duméril and paid surprisingly little attention to data (e.g., the maximum for subcaudals) and indications as the absence of supranumeral scutes in Schlegel (1837). Boettger (1888), for example, distinguished the nominal species "*Zamenis versicolor* Wagl." (i.e., *C. cliffordii*, see Early Descriptions) and *Z.* [auct.] *diadema* (comprising "var." *schirazana* [sic]) by the number of subcaudals, i.e., 74 or less versus 77-110, respectively. These data largely concur with the morphological boundary between *Spalerosophis diadema cliffordii* and more eastern Diadem snakes including *S. d. schirasianus* as demonstrated in this paper (Tb. 2, see penultimate paragraph below).

The diagnosis of *Periops parallelus schirasianus* Jan is short and simple (see Early Descriptions) and the more elaborate account in Jan (1865) entirely concerns with a comparison vis-à-vis Diadem snakes from "Egitto" (Egypt). Apart from differences in dorsal colour pattern, *schirasianus* is characterized ("può essere ritenuata per un buon carattere per distinguere dalle altre la varietà della Persia") by the separation of the proper prefrontals from the frontal, i.e., the virtually exclusive ("così costante") incidence of at least three supranumeral scutes (Jan, 1863).

Due to terminological confusion, the interpretation of information about the number of certain head scales from literature is sometimes a matter of guesswork, and many important papers on Diadem snakes (e.g., Schmidt, 1930, 1939; Marx, 1959; Minton, 1966) do not address, for instance, the configuration of scales in the prefrontal region. Minton's (1966) data for these scutes and the perioculars ("eight to 11" each) of 'eastern *diadema*' are definitely higher than documented in this study (Tb. 1), possibly to some degree due to our limited sample size (see Material and Methods). Marx's (1959) periocular data (9-11, mean 9.7) for 'eastern *diadema*' may include juvenile or subadult *Spalerosophis atriceps* (see Systematic Concept: second paragraph).

Forcart's (1950) remark regarding the separation (!) of the prefrontals from the frontal in three *Spalerosophis diadema schirasianus* (i.e., all except NHMB 14325) by

a single (!) intermediary scale ("Frontale durch ein Zwischenschildchen von den Praefrontalia getrennt") is irreproducible and requires re-examination of the specimens. This is also the case with three *S. d. cliffordii* from Khuzestan reported by Hellmich (1959) which have, depending on the terminology applied in their description and the interpretation thereof, a total of four to six or five to eight (including four flanking scales) prefrontals ("Praefrontalia links und rechts von zwei hintereinander stehen Schildchen flankiert"). The more cautious approach (4-6 scales), compatible with our findings (Tb. 1) and eliminating the possible inclusion of upper loreals (see Terminology), is taken in this analysis, but the state of affairs in Khuzestan and other areas needs careful consideration.

Considerable variation in the shape of the parietal is exemplified by the type series of all nominal species-group taxa examined for this study (Figs 1-2; Russell, 1807: Pl. XXX; Jan & Sordelli, 1867: Pl. II, including supposed syntype). In the case of *Coluber cliffordii* Schlegel and *Periops parallelus* Duméril, Bibron & Duméril, the last periocular is deeply wedged in between the supraocular and parietal in, for example, RMNH 467A and MNHN 3571; other specimens have the lateral edges of the parietals conspicuously reduced along its entire length (RMNH 467B) or at least constricted posteriorly (MNHN 3572-74, 1999.8250). Similar variation is observed in *Periops parallelus schirasianus* Jan & Sordelli; the lectotype of *C. diadema* Schlegel shows distinct reduction, i.e., a series of detached scales all along the exterior borders of the parietals.

Data for body scales (Tb. 2) clearly corroborate the validity of *Spalerosophis diadema schirasianus* (see smallprint below) and numeric results of Schmidt (1939) and Marx (1959), i.e., a small gap in subcaudal counts separating *S. d. cliffordii* of southern Iraq and Khuzestan (less than 75) from *S. d. schirasianus* (76 or more); these taxa are also distinct in their means of msr counts. 'Eastern *diadema*' show at least 95 subcaudals vis-à-vis fewer in *d. schirasianus* as well as more ventrals and msr (means); this morphological boundary slightly differs from the value (100) in Marx (1959). A more precise determination of the distinctive parameters between *schirasianus* and 'eastern *diadema*' and their geographical distribution requires larger samples (e.g., from the Baluchistan Region) and analyses of additional characters.

Due to their low number of subcaudals, we follow Mertens (1969) and classify two *Spalerosophis diadema* (SMF 50403 [♂], 50452) from southern Baluchistan (Pakistan) with 97 each (no other data reported) as intergrades between *S. d. schirasianus* and 'eastern *diadema*'. However, we consider problematical Mertens's (1969) allocation of SMF 57337 ("s.ad.") and 63044 (♀) from the vicinity of Mansehra (34°20'N 73°12'E) in North Pakistan with 244-248 ventrals, 95-102 subcaudals, and 29 msr to *schirasianus*. These counts and further data from the same general area (Boulenger, 1893: two specimens from "Punjab") as well as the over-all ranges (including material from northern Pakistan) reported by Marx (1959) and Minton (1966) qualify populations of Diadem snakes from Punjab, Northwest Frontier Province, and Chitral (Wall, 1911b) as 'eastern *diadema*'.

We believe that Afghan populations of 'eastern *diadema*' are restricted to the border areas with northern Pakistan. Two specimens from Jalalabad (Nangarhar Province, no morphological data indicated) in Northeast Afghanistan "show identical

characters" with "the nominate subspecies" (Král, 1969), i.e., probably at least 234 (in case of ♂♂) or 246 (♀♀) ventrals and more than 100 subcaudals (Marx, 1959). However, a male (FMNH 161057) from the Kabul area (Paghman) with 227 ventrals and 27 msr (subcaudals incomplete) fits *Spalerosophis diadema schirasianus* (Anderson & Leviton, 1969). A subadult (♀?) Diadem snake in the BMNH collection from "Afghanistan" with 247 ventrals, 100 subcaudals, and 27 msr (Boulenger, 1893: letter ζ) not included in our analysis (Tb. 2) may be an intergrade based on its low number of dorsal scale rows, but the maximum at midbody (see Terminology) requires verification. The unlocated specimen (♂) with 237 ventrals and 110 subcaudals from "Afghanistan" or Karachi ("Kurrachee") described by Günther (1864) is tentatively assigned to 'eastern *diadema*'; it cannot be completely ruled out that one or several of his individuals from Sind (Karachi) belong to *S. atriceps*. Due to notorious confusion of these species, this study does not address the detailed distribution limits of *S. diadema* to the east, probably situated in Northwest India (see Systematic Concept: second paragraph).

The data compiled for this study clearly demonstrate that the supposedly lost type series of *Coluber diadema* Schlegel (see Early Descriptions: first smallprint) has definitely less ventrals (220-238, possibly encompassing preventrals) than 'eastern *diadema*', and the subcaudal count of 61 (Russell, 1807) in the lectotype is far too low vis-à-vis *Spalerosophis diadema schirasianus* and 'eastern *diadema*' (Tb. 2) as highlighted by Lanza (1964). Thus, the origin of *C. diadema* Schlegel, i.e., the vicinity of Bushehr (Russell, 1807), remains questionable. A juvenile male "*Spalerosophis shirazianus*" [sic] from near "Bushire" reported by Schmidt (1955) has 87 subcaudals and 228 ventrals, prompting Leviton *et al.* (1992) to indicate *S. d. schirasianus* from "the coastal plain [...] in the vicinity of Bushire" (their comment regarding Schmidt's data set and status of the taxon ["this subspecies"] is inaccurately formulated; two out of three specimens including one from the Teheran area are "in bad state" [Schmidt, 1955] and without data). This poses the question whether the seaport might just have been the place of dispatch of "Mr." Bruce's shipment (Russell, 1807), and it cannot be completely excluded that the type series of *C. diadema* was not collected in the immediate surroundings of Bushehr. In this context, it is necessary to emphasize that no further individual body scale data for *S. diadema* from along the Persian Gulf are known for the time being (Rajabizadeh *et al.*, 2008: map). For the sake of completeness, the reader should also be reminded that the illustration in Russell (1807: Pl. XXX) shows an apparently undamaged tail with 63 (instead of 61) paired subcaudals, and as few as 60 are found in Jan & Sordelli's (1867: Pl. II.B) smaller *schirasianus* from "Schiraz". Two exceedingly low counts (66, 60) from "Karmán" (Blanford, 1876) and Fallujah (Corkill, 1932) were omitted from analysis (see Terminology).

The number of midbody scale rows in the type series of *Coluber diadema* Schlegel is not documented, nor did the description pay attention to "an unusual row" of scales behind the larger prefrontals (Russell, 1807). The lectotype has five supranumeral scutes (see Early Descriptions) but this condition, as well as the total number of scales in the prefrontal region, do not permit a definite conclusion as to its probable origin. In view of the exceedingly low number of subcaudals, it cannot be completely ruled out that the type series of *C. diadema*, and in particular the male lectotype, was collected between Bushehr and Fars (Shiraz). We are not aware of any published body scale data from that area; although Werner (1917) quoted "*Zamenis diadema*" obtained at "Tangistân" near Ahram (Bushehr Province) and "Buschähr" from field notes of

Friedrich Carl Andreas, no preserved material is present in this collection. Should Russell's (1807) specimens actually originate from generally north of Bushehr, *Periops parallelus schirasianus* Jan could turn out to be a junior synonym of *C. diadema* Schlegel. This would nolens volens corroborate Baig & Masroor's (2008) attitude, which is entirely based on the supposed type locality and, unspoken, sympatry with *Spalerosophis diadema schirasianus*. By all means, these authors did not explicitly provide a rationale for their conclusion that "*schirazianus* [sic] is a junior synonym" of *diadema*; this opinion is due to a lack of comparative material and a biased systematic concept, namely the uncritical allocation of all Pakistani Diadem snake populations to the nominate subspecies of *S. diadema*. To judge from their text and data, Baig & Masroor (2008: 110, Fig. 6, Tb. 1) did not examine any *schirasianus* at all. PMNH 1922-23 with 246-255 ventrals, 107-109 subcaudals, and probably 29 msr (see Terminology) from Karak at "the western boundary of Pakistan, adjacent to Afghanistan" belong to 'eastern *diadema*'; they are assumed to come from near 33°07'N 71°06'E or 34°26'N 72°44'E in the Northwest Frontier Province, and not from Karak in Baluchistan (30°20'N 66°44'E).

At any rate, the subcaudal count of the lectotype of *Coluber diadema* Schlegel renders illusory the distinctive feature between *Spalerosophis diadema cliffordii* and *S. d. diadema* sensu stricto, and morphological data (ventral and subcaudal counts) of *C. diadema* best fit Diadem snakes from Khuzestan and southern Iraq. If this turned out to be correct, western populations (*S. d. cliffordii* auct.) should be allocated to the nominate subspecies (e.g., Chernov, 1959; Lanza, 1964; see Schätti *et al.*, 2009b). Awaiting further field work in, or the study of museum material from, the northern Persian Gulf and areas farther inland, we respect conventional usage for western Diadem snakes from Khuzestan to the west (*S. d. cliffordii*) and recommend to refer to 'eastern *diadema*' as *S. d. diadema* auct. In any event, the latter require a new name and further decisions regarding the subspecific allocation of populations from Iraq and Khuzestan depend upon comparison with Clifford's Diadem snake from North Africa to Arabia (see below).

To the best of our knowledge, the only potentially available name for 'eastern *diadema*' is *Zamenis diadema* var. *melanoides* Wall, 1914 earlier described as variety "C" (Wall, 1911a), but this taxon is supposed to be a junior synonym of *Spalerosophis atriceps* (Fischer). Uniting all populations of Diadem snakes from the southeastern Caspian area and the Zagros Range to the east under *S. diadema schirasianus* while maintaining *S. d. cliffordii* for populations from Iraq and Khuzestan would result in the suspension of the nominotypical subspecies.

Irrespective of the erroneous assumption regarding the type locality of *Spalerosophis diadema* ("near Bombay"), Marx (1959) is correct that *S. d. schirasianus* proves to be "morphologically intermediate" between the western *S. d. cliffordii* and *S. d. diadema* auct. "of Pakistan and India [...] in ventral and caudal counts of both sexes". However, Schmidt's view (1939) that *schirasianus* "may be more closely allied to the true *diadema* [auct.] (of north-western India)" is possibly more precise, at least to judge from morphological characters analyzed by us as well as biogeographical considerations.

The distinction between *Spalerosophis diadema cliffordii* and *S. d. schirasianus* entirely relies on differences in subcaudal counts (Schmidt, 1930, 1939; Marx, 1959). "The reference of specimens from Iraq to *cliffordii* instead of to *diadema* auct. is made necessary by the recognition of *schirazianus* [sic] from Iran, inserted between the type locality of *diadema* (Bombay) [!], and the Iraqi (Mesopotamian) area", but Schmidt (1939) admitted that this "is by no means a completely satisfactory allocation. The

alternative is to give a new name to the form in the Euphrates Valley [!], and it is preferable to reserve the proposal of additional names for a more comprehensive revision pending which trinominals are avoided." We take this opportunity to clarify that the situation in Iraq is more complex than described so far. Corkill (1932) reported a probable female Diadem snake from As-Sulaymaniyah (35°34'N 45°26'E) in Northeast Iraq with 233 ventrals, "87" subcaudals (possibly 78), and as many as 35 msr. It differs from all *cliffordii* analyzed within the scope of this study (Tb. 2) and specimens from Southeast Turkey and Syria with 202-219 ventrals (♂♂ 202-205, ♀♀ 215-219), 65-72 subcaudals (69-72, 65-72), and 29-32 (29-31, 31-32 [maximum probably 33 as indicated in Schätti *et al.*, 2009a: 131-132 [key]) msr (Eiselt, 1970; Baran, 1982; Franzen, 1999; Baran *et al.*, 2004; Sindaco *et al.*, 2006). These latter populations differ vis-à-vis *cliffordii* auct. from the area under consideration in distinctly lower ventral counts. It is noteworthy that Marx's (1959) working sample of *cliffordii* includes FMNH 19596 from Sinjar in western Kurdistan.

Species status for *Coluber cliffordii* Schlegel (see Systematic Concept: fifth paragraph) is not an idea to be a priori rejected but we refrain from any decision concerning its systematic status because this study does not scrutinize morphological variation in populations from North Africa, in particular Libya (type locality: Tripoli), to the Near East nor resolve the quandary regarding the correct scientific name of Diadem snakes from west of a line along the Zagros Range to Bushehr Province as explained in this paper.

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## REFERENCES

AFRASIAB, S. R. & ALI, H. A. 1989. Report on a collection of reptiles from Rumaila Desert, south of Iraq. *Bulletin of the Iraq natural History Museum* 8 (2): 65-73.

ANDERSON, S. C. & LEVITON, A. E. 1969. Amphibians and reptiles collected by the Street expedition to Afghanistan, 1965. *Proceedings of the California Academy of Sciences* [4] 37 (2): 25-56.

BAIG, K. J. & MASROOR, R. 2008. The snakes of the genus *Spalerosophis* Jan, 1865 in Indo-Pakistan and Iran (Squamata: Serpentes: Colubridae). *Herpetozoa* 20 (3/4): 109-115.

BARAN, I. 1982. Zur Taxonomie der Schlangen in Südost- und Ost-Anatolien. *Spixiana* 5 (1): 51-59.

BARAN, I., KUMULTAŞ, Y., ILGAZ, Ç., TÜRKOZAN, O. & A. AVCI, A. 2004. New locality records extended the distribution of some ophidians in southeastern Anatolia. *Russian Journal of Herpetology* 11 (1): 6-9.

BRANCA, G. 1869. I viaggiatori italiani del nostro secolo [continued]. *Bollettino della Società Geografica Italiana* 3: 317-409.

BISWAS, S. & SANYAL, D. P. 1977. Fauna of Rajasthan, India, Part: Reptilia. *Records of the Zoological Survey of India* 73: 247-269.

BLANFORD, W. T. 1876. Eastern Persia. An account of the journeys of the Persian Boundary Commission 1870-71-72. Vol. II. The Zoology and Geology. *London, Macmillan & Co.*, VIII + 516 pp.

BLANFORD, W. T. 1881. On a collection of Persian reptiles recently added to the British Museum. *Proceedings of the Zoological Society of London* 1881 (3): 671-682.

BOETTGER, O. 1885. Liste der von Hrn. Dr. med. W. Kobelt in Algerien und Tunisien [sic] gesammelten Kriechthiere (pp. 457-475). *In*: KOBELT, W. Reiseerinnerungen aus Algerien und Tunis. *Frankfurt am Main, Moritz Diesterweg*, VIII + 480 pp.

BOETTGER, O. 1888. Die Reptilien und Batrachier Transkaspiens. *Zoologische Jahrbücher, Abtheilung für Systematik, Geographie und Biologie der Thiere* 3: 871-972.

BOULENGER, G. A. 1890. The Fauna of British India, including Ceylon and Burma. Reptilia and Batrachia. *London, Taylor and Francis*, XVIII + 541 pp.

BOULENGER, G. A. 1893. Catalogue of the snakes in the British Museum (Natural History). Vol. 1. *London, Trustees of the British Museum (Natural History)*, XIII + 448 pp.

BOULENGER, G. A. 1893-1896. Catalogue of the snakes in the British Museum (Natural History). 3 Vols. *London, Trustees of the British Museum (Natural History).*

BOULENGER, G. A. 1906. Reptiles and Batrachians (pp. 517-531). *In*: The history of the collections contained in the natural history departments of the British Museum. Vol. II. Separate historical accounts of the several collections included in the department of Zoology. *London, Trustees of the British Museum*, [3+] 782 pp.

CAPOCACCIA, L. 1961. Catalogo dei tipi di rettili del Museo Civico di Storia Naturale di Genova. *Annali del Museo Civico di Storia Naturale „Giacomo Doria„* LXXII: 86-111.

CHERNOV, S. A. 1959. Fauna Tadzhikskoj SSR. Tom XVIII [Trudy XCVIII]. Presmykajuszcziesja [Fauna of Tadzhikistan. Vol. XVIII. Reptiles]. *Stalinabad [Dushanbe], Akademija Nauk Tadzhikskoj SSR*, 204 pp.

CONSTABLE, J. D. 1949. Reptiles from the Indian Peninsula in the Museum of Comparative Zoology. *Bulletin of the Museum of Comparative Zoology at Harvard College* 103 (2): 59-160.

CORKILL, N. L. 1932. The snakes of Iraq. *Journal of the Bombay Natural History Society* 35: 552-572.

DAUDIN, F. M. 1803a. Histoire naturelle, générale et particulière des reptiles. Tome sixième. *Paris, F. Dufart*, 447 pp.

DAUDIN, F. M. 1803b. Histoire naturelle, générale et particulière des reptiles. Tome septième. *Paris, F. Dufart*, 436 pp.

DE FILIPPI, F. 1862. Nuove o poco note specie di animali vertebrati raccolte in un viaggio in Persia nell' estate dell' anno 1862. *Archivio per la Zoologia, l' Anatomia e la Fisiologia*, II (2): 377-394.

DE FILIPPI, F. 1863. Note di un viaggio in Persia nel 1862. *Milano, G. Daelli & C. Editori*, VIII [+ 2] + 396 [+ 2] pp.

DUMÉRIL, A. M. C., BIBRON, G. & DUMÉRIL, A. 1854. Erpétologie générale ou histoire naturelle complè te des reptiles. Tome septième. Première partie. *Paris, Roret*, XVI + 780 pp.

EISELT, J. 1970. Ergebnisse zoologischer Sammelreisen in der Türkei: Bemerkenswerte Funde von Reptilien, I. *Annalen des Naturhistorischen Museums in Wien* 74: 343-355.

FISCHER, J. G. 1885. Ichthyologische und herpetologische Bemerkungen. 5. Herpetologische Bemerkungen. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten* 2 [1884]: 82-121.

FORCART, L. 1950. Amphibien und Reptilien von Iran. *Verhandlungen der naturforschenden Gesellschaft Basel* 61: 141-156.

FORSKÅL, P. 1775. Descriptiones animalium avium, amphibiorum, piscium, insectorum, vermium quae in itinere orientali observavit Petrus Forskål. Post mortem auctoris edidit Carsten Niebuhr. *Haunia [Copenhagen], Möller*, 20 + XXXIV + 164 pp.

FRANZEN, M. 1999. A record of *Spalerosophis diadema* (Reptilia: Colubridae) from Adıyaman province, Turkey. *Zoology in the Middle East* 19: 33-36.

GASPERETTI, J. 1988. Snakes of Arabia. *Fauna of Saudi Arabia* 9: 169-450.

GEOFFROY SAINT-HILAIRE, I. 1827. Description des reptiles qui se trouvent en Égypte (pp. 121-160). *In*: SAVIGNY, J. C. Description de l'Égypte ou recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de l'armée française (1798-1801). I. Histoire naturelle. Part 1. *Paris, Imprimerie Impériale*.

GISTEL, J. 1848. Naturgeschichte des Thierreichs. Für höhere Schulen. *Stuttgart, Hoffmann'sche Verlags-Buchhandlung*, XVI + 216 [+ 4 ("Erklärung der Figuren des Atlas")] pp. and atlas [32 plates].

GISTEL, J. 1850. System des Thierreich (pp. 226-626). *In*: GISTEL, J. & BROMME, T. Handbuch der Naturgeschichte aller drei Reiche, für Lehrer und Lernende, für Schule und Haus. *Stuttgart, Hoffmann'sche Verlags-Buchhandlung*, [2 +] 1037 pp. [48 col. plates].

GISTEL, J. 1868. Die Lurche Europas. Ein Beitrag zur Lehre von der geographischen Verbreitung derselben (pp. 144-167). *In*: Blick in das Leben der Natur und des Menschen [...]. *Leipzig, Gb. Wartig*, 274 pp.

GMELIN, J. F. 1789. Caroli A Linné, Systema naturae [...]. Editio decima tertia, aucta, reformata. Tom. I. Pars III [pp. 1033-1516, Amphibia pp. 1033-1125]. *Lipsia [Leipzig], G. E. Beer*.

GRAY, J. E. 1831. A synopsis of the species of the class Reptilia (Appendix, pp. 1-110). *In*: GRIFFITH, E. & PIDGEON, E. (eds). The Animal Kingdom arranged in conformity with its organization, by the Baron Cuvier [...] with additional descriptions of all the species hitherto named, and of many not before noticed. Vol. the ninth. The Class Reptilia [...] with specific descriptions. *London, Whittaker, Treacher, and Co.*, [7 +] 481 + 110 pp. [reprint 1996, *Bredell (S. Africa), Herprint International CC*].

GRAY, J. E. 1849. Catalogue of the specimens of snakes in the collection of the British Museum. *London, E. Newman* [printed by order of the Trustees], XV + 125 pp.

GÜNTHER, A. 1858. Catalogue of colubrine snakes in the collection of the British Museum. *London, Trustees of the British Museum*, XVI + 281 pp. [reprint 1971, *Oxford, Alden Press*].

GÜNTHER, A. 1864. The reptiles of British India. *London, R. Hardwicke* [Ray Society], XXVII + 452 pp.

HALLERMANN, J. 2007. Zur Geschichte der herpetologischen Sammlung des Zoologischen Museums Hamburg, mit besonderer Berücksichtigung von Dr. Johann Gustav Fischer (1819-1889). *Sekretär* 7 (1): 20-31.

HELLMICH, W. 1959. Bemerkungen zu einer kleinen Sammlung von Amphibien und Reptilien aus Süd-Persien. *Opuscula Zoologica* 35: 1-9.

[ICZN] INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE 1986. Opinion 1384. *Dromophis* Peters, 1869 (Reptilia, Serpentes): conserved. *Bulletin of Zoological Nomenclature* 43: 123-124.

[ICZN] INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE 1996. Opinion 1856. *Lycognathophis* Boulenger, 1893 (Reptilia, Serpentes): conserved. *Bulletin of Zoological Nomenclature* 53: 226-227.

[ICZN] INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE 1999. International code of zoological nomenclature (4th ed.). *London, The International Trust for Zoological Nomenclature*, XXIX + 306 pp.

JAN, G. 1863. Elenco sistematico degli ofidi descritti e disegnati per l'iconografia generale. *Milano, A. Lombardi*, VII + 143 pp.

JAN, G. 1865. Prime linee d'una fauna della Persia occidentale (pp. 341-363). *In*: DE FILIPPI, F. Note di un viaggio in Persia nel 1862. *Milano, G. Daelli & C. Editori*, VIII [+ 2] + 396 [+ 2] pp.

Jan, G. & Sordelli, F. 1867. Iconographie générale des ophidiens. Tome second, 20e livraison. *Milan* and *Paris, F. Sordelli* and *J. B. Baillière et Fils* [6 plates, including 'Index des planches' on inside of cover].

Khalaf, K. T. 1960. Notes on a collection of lizards and snakes from Iraq. *Iraq Natural History Museum Publication* 18: 12-18.

Khan, M. S. 1986. A noteworthy collection of amphibians and reptiles from north-eastern Punjab, Pakistan. *The Snake* 18: 118-125.

Khan, M. S. 2006. Amphibians and Reptiles of Pakistan. *Malabar, Krieger*, XVI + 311 pp.

Král, B. 1969. Notes on the herpetofauna of certain provinces of Afghanistan. *Zoologické Listy* 18 (1): 55-66.

Kramer, E. & Schnurrenberger, H. 1963. Systematik, Verbreitung und Ökologie der Libyschen Schlangen. *Revue suisse de Zoologie* 70 (3): 453-568.

Kucharzewski, Ch. & Tillack, F. 2008. The identity of *Cochliophagus isolepis* Müller 1924 (Serpentes: Colubridae). *Salamandra* 44 (1): 43-49.

Lantz, L. A. 1918. Reptiles from the River Tajan (Transcaspia). *Proceedings of the Zoological Society of London* 1918 (1-2): 11-17.

Lanza, B. 1964. Il genere *Sphalerosophis* [sic] e descrizione di una nuova specie (Reptilia, Serpentes). *Monitore zoologico italiano* 72 (1-2): 47-64.

Latifi, M. 1991. The snakes of Iran [1985]. Leviton, A. E. & Zug, G. R. (eds). Contributions to herpetology. Vol. 7. *Oxford [Ohio], Society for the Study of Amphibians and Reptiles*, VII + 159 pp. [translated from Farsi].

Leviton, A. E., Anderson, S. C., Adler, K. & Minton, S. A. 1992. Handbook to Middle East amphibians and reptiles. Contributions to herpetology. Vol. 8. *Oxford [Ohio], Society for the Study of Amphibians and Reptiles*, VII + 252 pp.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, diferentiis, syonymis, locis. Editio decima, reformata; Tomus I. *Holmia [Stockholm], Laurentius Salvius*, 823 pp. [reprint 1956, *London, British Museum (Natural History)*].

Linnaeus, C. 1766. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, diferentiis, syonymis, locis. Editio duodecima, reformata. Tomus I. *Holmia [Stockholm], L. Salvius*, 532 pp.

Marx, H. 1959. Review of the colubrid snake genus *Spalerosophis*. *Fieldiana, Zoology* 39 (30): 347-361.

Merrem, B. 1820. Versuch eines Systems der Amphibien [Tentamen Systematis Amphibiorum]. *Marburg, J. C. Krieger*, XV + 191 pp.

Mertens, R. 1921. Ichthyologisches und Herpetologisches aus J. Gistels „Naturgeschichte des Thierreichs". *Senckenbergiana* 3 (6): 170-178.

Mertens, R. 1940. Bemerkungen über einige Schlangen aus Iran. *Senckenbergiana* 22 (3/4): 244-259.

Mertens, R. 1956. Amphibien und Reptilien aus SO-Iran 1954 (Ergebnisse der Entomo - logischen Reisen Willi Richter, Stuttgart, im Iran 1954 und 1956 - Nr. 5). *Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg* 111 (1): 90-97.

Mertens, R. 1969. Die Amphibien und Reptilien West-Pakistans. *Stuttgarter Beiträge zur Naturkunde* 197: 1-96.

Minton, S. A., Jr. 1966. A contribution to the herpetology of West Pakistan. *Bulletin of the American Museum of Natural History* 134 (2): 29-184.

Pieper, H. 1996. Johann Gistel und die Erforschung der Mäuse in Bayern. *Bonner zoologische Beiträge* 46 (1-4): 283-285.

Rajabizadeh, M., Feizi, H., Qasemi, M., Ram, M. & Heidari, F. 2008 [1387]. Reptile fauna of Hormozgan Province (islands, seashores, and mainland) in southern Iran. *Kerman, International Center for Science, High Technology and Environmental Science*, 92 pp. [in Farsi, unpublished].

RAZOUMOWSKY, G. DE 1789. Histoire naturelle du Jorat et de ses environs; et celle des trois lacs de Neufchatel, Morat et Bienne [...]. Tome Premier. *Lausanne, Jean Mourer*, XVI + 322 pp.

ROOIJEN, J. VAN & VOGEL, G. 2008. An investigation into the taxonomy of *Dendrelaphis tristis* (Daudin, 1803): revalidation of *Dipsas schokari* (Kuhl, 1820) (Serpentes, Colubridae). *Contributions to Zoology* 77 (1) 33-43.

RUSSELL, P. 1796. An account of Indian serpents collected on the Coast of Coromandel [...]. *London, W. Bulmer and Co. Shakspeare Press*, VIII + 91 pp. [46 plates].

RUSSELL, P. 1801-1809 [1810?]. A continuation of an account of Indian serpents [...]. Sections 1-5. London, W. *Bulmer and Co. Shakspeare Press*, V + 7 [IX-XV] + 53 pp. [45 plates].

RUSSELL, P. 1807. A continuation of an account of Indian serpents; containing descriptions and figures, from specimens and drawings, transmitted from various parts of India [...]. Section 4 [pp. 29-38, plates 25-32]. *London, W. Bulmer and Co. Shakspeare Press* [for G. and W. Nicol, Booksellers to His Majesty].

SCALI, S. 1995. Sezione di zoologia dei vertebrati (pp. 248-292). In: LEONARDI, M. & QUARONI, A. & RIGATO, F. & SCALI, S. Le collezioni del Museo Civico di Storia Naturale di Milano. *Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale, Milano* 135 [1994]: 3-296.

SCHÄTTI, B., TILLACK, F. & HELFENBERGER, N. 2009a. A contribution to *Spalerosophis microlepis* JAN, 1865, with a short review of the genus and a key to the species (Reptilia: Squamata: Colubridae). *Herpetozoa* 22 (3/4): 115-135.

SCHÄTTI, B., TILLACK, F. & KUCHARZEWSKI, Ch. 2009b. Identität und Status dreier aus Ägypten beschriebener Schlangenarten: *Coluber tyria* Linnaeus, 1758, *Coluber cahirinus* Gmelin, 1789 und *Coluber geoffroyii* Gray, 1831 (Squamata: Serpentes: Colubridae). *Herpetozoa* 22 (1/2): 43-54.

SCHÄTTI, B., TILLACK, F. & SCHULZ, K.-D. 2010. History, status, and validity of the Racer *Zamensis persicus* Jan, 1863, and the scientific name of the Ratsnake *Z. persicus* (Werner, 1919) (Squamata: Colubridae). *Zoosystematics* and *Evolution* 86 (2): 275-281.

SCHLEGEL, H. 1837. Essai sur la physionomie des serpens. 2 volumes and atlas. *La Haye, Kips & Stockum*, [7 +] 27 [II-XXVIII] + 251 [+ 1] pp. and [6 +] 606 [+ 2] + XV ["Table alphabétique"] [+ 1 ("Errata")] pp., [2 pp. +] XXI plates + 3 maps + 2 tables + 1 p. ["Liste des planches, cartes et tableaux contenus dans l'Atlas"].

SCHMIDT, K. P. 1930. Reptiles of Marshall Field North Arabian desert expeditions, 1927-1928. *Field Museum of Natural History, Zoological Series* 17 (6): 223-230.

SCHMIDT, K. P. 1939. Reptiles and amphibians from southwestern Asia. *Field Museum of Natural History, Zoological Series* 24 (7): 49-92.

SCHMIDT, K. P. 1955. Amphibians and reptiles from Iran. *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i København* 117: 193-207.

SCHMIDT, K. P. & MARX, H. 1957. Results of the NAMRU-3 southeastern Egypt expedition, 1954. 2. Reptiles and amphibians. *Bulletin of the Zoological Society of Egypt* 13: 16-28.

SHAH, K. B. & TIWARI, S. 2004. Herpetofauna of Nepal. A conservation companion. *Kathmandu, IUCN Nepal*, VIII + 237 pp.

SHERBORN, C. D. 1929. Index animalium sive index nominum quae ab A. D. MDCCLVIII generibus et speciebus animalium imposita sunt. Sectio Secunda [1801-1850]. Part 21 [pp. 5139-5348]. *London, Trustees of the British Museum.*

SINDACO, R. SERRA, G. & MENEGON, M. 2006. New data on the Syrian herpetofauna with a newly-recorded species of snake. *Zoology in the Middle East* 37: 29-38.

SMITH, M. A. 1926. Monograph of the sea snakes (Hydrophiidae). London, Trustees of the British Museum, XVII + 130 pp. [2 plates] [reprint 1971, *Codicote* and *Weinheim, Wheldon & Wesley* and *J. Cramer*].

SMITH, M. A. 1943. The Fauna of British India, Ceylon and Burma, including the whole of the Indo-Chinese sub-region. Reptilia and Amphibia. Vol. III. Serpentes. *London, Taylor & Francis*, XII + 583 pp.

STRAUCH, A. 1873. Die Schlangen des Russischen Reichs, in systematischer und zoogeographischer Beziehung [geschildert]. *Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg* [7] 21 (4): 1-287.

TERENTJEV, P. V. & CHERNOV, S. A. 1936. Kratkij opredelitel zemnovodnych i presmykajuszczichsja SSSR [Short determination guide to the amphibians and reptiles of the USSR]; *Moskva [Moscow] & Leningrad, Gosudarstvennoje Učebno-Pedagogicheskoe Izdatelstvo*, 95 pp.

TRAPE, J.-F. & MANÉ, Y. 2006. Guide des serpents d'Afrique occidentale, Savane et désert. *Paris, IRD*, 226 pp.

WAGLER, J. 1830. Natürliches System der Amphibien, mit vorangehender Classification der Säugethiere und Vögel. *München, Stuttgart und Tübingen, J. G. Cotta*, VI + 354 pp.

WALL, F. 1909. A monograph of the sea snakes. *Memoirs of the Asiatic Society of Bengal* 2 (8): 169-251 [4 plates].

WALL, F. 1911a. Remarks on the snake collection in the Quetta Museum. *Journal of the Bombay Natural History Society* 20 (4) [1910]: 1033-1042.

WALL, F. 1911b. Reptiles collected in Chitral. *Journal of the Bombay Natural History Society* 21 (1): 132-145.

WALL, F. 1914. A popular treatise on the common Indian snakes. Part XXIII [*Coluber radiatus, Zamenis diadema*]. *Journal of the Bombay Natural History Society* 23 (2): 206-215.

WERNER, F. 1895. Ueber eine Sammlung von Reptilien aus Persien, Mesopotamien und Arabien. *Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien* 45 (1): 13-20.

WERNER, F. 1917. Reptilien aus Persien (Provinz Fars). *Verhandlungen der kaiserlich-königlichen zoologisch-botanischen Gesellschaft in Wien* 67 (5/6): 191-220.

WERNER, F. 1923. Neue Schlangen des Naturhistorischen Museums in Wien. *Annalen des Naturhistorischen Museums in Wien* 36: 160-166.

WERNER, F. 1936. Reptilien und Gliedertiere aus Persien (pp. 193-204). *In*: Festschrift zum 60. Geburtstage von Prof. Dr. Embrik Strand. Vol. II. *Riga, Spiestuve "Latvija"*, 652 pp.

WHITAKER, R. & CAPTAIN, A. 2004. Snakes of India. The field guide. *Chennai, Draco Books*, XIV + 481 pp.

ZUGMAYER, E. 1905. Beiträge zur Herpetologie von Vorder-Asien. *Zoologische Jahrbücher, Abteilung für Systematik, Geographie, Biologie der Tiere* 23(4): 449-486.

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# Redescription of *Vermaia pseudotropii*, a hyperapolytic freshwater tapeworm, and composition of *Vermaia* Nybelin, 1942 (Cestoda: Proteocephalidea)

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**Redescription of *Vermaia pseudotropii*, a hyperapolytic freshwater tapeworm, and composition of *Vermaia* Nybelin, 1942 (Cestoda: Proteocephalidea). -** The cestode *Vermaia pseudotropii* (Verma, 1928) (Proteocephalidea: Gangesiinae), a parasite of the catfish *Clupisoma garua* (Siluriformes: Schilbeidae) in India and the only known hyperapolytic proteocephalidean, is redescribed based on freshly collected material from the type-host from West Bengal, India. Surface structures, including giant coniform spinitriches on the rostellum-like organ, are described for the first time using scanning electron microscopy and new morphological data on the rostellum-like organ and its armature, terminal genitalia, uterine development, longitudinal internal musculature and egg morphology are provided. *Vermaia pseudotropii* is characterized by hyperapolysis and several morphological autapomorphies, such as the shape and arrangement of large hooks (62-69 $\mu$m long) on the rostellum-like organ; very short lateral bands of vitelline follicles, which are limited to the preovarian region posterior to the cirrus-sac level and the length of which represents only 14-18% of the proglottis length; "spined" cirrus (the distal part covered with long spini - triches); and an ampullaceous vaginal atrium. The validity of the genus *Vermaia* Nybelin, 1942 is also confirmed and its species are reviewed. *Gangesia sumani* Shinde & Wankhede, 1990 is synonymized with *V. pseudotropii*. The present study revealed conspecificity of *Gangesia (Vermaia) jammuensis* (Fotedar & Dhar, 1974) with *Gangesia agraensis* Verma, 1928. *Vermaia sorrakowahi* Zaidi & Khan, 1976 differs from *V. pseudotropii* in the distribution of vitelline follicles, the pre-ecuatorial position of the cirrus-sac, number and size of hooks on the rostellum-like organ, and number of testes.

**Keywords:** Morphology - Gangesiinae - scanning electron microscopy - *Clupisoma garua* - India.

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## INTRODUCTION

*Vermaia pseudotropii* was described as *Gangesia pseudotropii* from the catfish *Pseudotropius garua* (Hamilton, 1822) (= *Clupisoma garua*) (Siluriformes: Schilbeidae) from Allahabad, Uttar Pradesh, India by Verma (1928). The author provided a fairly detailed morphological description of the species, including five illustrations of the scolex and its "rostellar" hooks, and 8 photomicrographs of proglottides and their cross sections. However, some data on the morphology of genital organs, such as the ovary and terminal genitalia, were missing. Verma (1928) also provided only a very few basic measurements of *G. pseudotropii*, such as the total length and maximum width, and size of the scolex and proglottides.

Nybelin (1942) (not Wardle & McLeod, 1952 as given by Yamaguti, 1959 – pp. 146 & 147) proposed to accommodate *G. pseudotropii* in a new genus, *Vermaia*, but he did not provide a true generic diagnosis. In fact, he just mentioned (Nybelin, 1942 – p. 18) two differences, in which the genus he proposed differed from other proteocephalidean genera, including *Gangesia* Woodland, 1924, namely an apolytic strobila and a unique arrangement of vitelline follicles. A much more detailed generic diagnosis of *Vermaia* was provided by Freze (1965), who compiled data from Verma's (1928) description of the type species of the genus.

Recently, new material of *V. pseudotropii* was collected from West Bengal, India. Its evaluation made it possible to supplement the original description by new morphological data, e.g. on the armature of the scolex, surface morphology (microtriches) as revealed by scanning electron microscopy (SEM), details of the genital system and morphology of the eggs. The taxonomic status of other two species previously placed in *Vermaia*, as well as that of *Gangesia sumani* Shinde & Wankhede, 1990, which closely resembles *V. pseudotropii* in its morphology, was also critically evaluated.

## MATERIALS AND METHODS

Tapeworms were collected from garua bachcha, *Clupisoma garua* (Hamilton, 1822) (synonym *Pseudotropius garua*), in West Bengal, India in 2009 by the present authors (A.A., T.S. and P.K.K.). All specimens were alive because they were obtained from alive or fresh fish that were dissected on a fishing boat on the Mukutmanipur dam lake soon (at maximum within 1-2 hours) after their capture. Specimens used for morphological studies, including SEM observations and histology, were rinsed in saline (physiological solution = 0.9% NaCl), placed in a small amount of saline in a beaker or big vial, and hot, almost boiling 4% formaldehyde solution (= formalin) was immediately added to keep worms stretched, not contracted or deformed (see Oros et al., 2010 for more data on this fixation procedure). After 2-3 weeks, formalin was replaced by 70% ethanol for storage before further processing of specimens (staining, sectioning or preparation for SEM observations).

For light microscopy, specimens were stained with Mayer's hydrochlorid carmine, destained in 70% acid ethanol (i.e. 80% ethanol with 2 ml of HCl in 100 ml), dehydrated through a graded ethanol series, clarified in clove oil (eugenol), and mounted in Canada balsam as permanent preparations. Pieces of the strobila were embedded in paraffin wax, cross-sectioned (thickness 12-15 $\mu$m), stained with

Weigert's haematoxylin and counterstained with 1% acidic eosin B (Scholz & Hanzelová 1998). Illustrations were made using a drawing attachment of an Olympus BX51 microscope with the use of Nomarski interference contrast. Measurements (in micrometres unless otherwise stated) were taken using Olympus Image-Pro programme; "n" represents the number of measurements. Eggs released from the uterus in the water were measured and illustrated using a Leitz DMLB microscope. For SEM studies, specimens were dehydrated through a graded ethanol series, followed by a graded amylacetate series, dried by a critical-point method, sputtered with gold and examined with a Jeol JSEM 7401F microscope (Oros et al., 2010). Terminology of microtriches follows that of Chervy (2009); names of fishes follow those of Froese & Pauly (2010).

The type specimens of *V. pseudotropii*, reported by Verma (1928) to have been deposited in the Zoological Survey of India in Calcutta (Kolkata), appear to be missing because they were not found during visit of two of the authors (P.K.K. and T.S.) in this institution in March 2009.

***Vermaia pseudotropii*** (Verma, 1928) Nybelin, 1942 Figs 1–26
*Gangesia pseudotropii* Verma, 1928
*Gangesia sumani* Shinde & Wankhede, 1990 **new synonym**

TYPE- AND ONLY HOST: *Clupisoma garua* (Hamilton, 1822) (Siluriformes: Schil - beidae).

TYPE LOCALITY: Allahabad, Uttar Pradesh, India.

GEOGRAPHICAL DISTRIBUTION: India (Maharashtra – as *Gangesia sumani*, Uttar Pradesh, West Bengal).

DEPOSITION OF SPECIMENS: The Natural History Museum, London, UK (acronym BMNH – 2010.7.26.2-3); Helminthological Collection, Institute of Parasitology, BC AS CR, České Budějovice, Czech Republic (IPCAS C-566); H.W. Manter Laboratory, University of Nebraska State Museum, Lincoln, USA (HWML 49499-49500); Natural History Museum, Geneva, Switzerland (MHNG INVE 63247, 68393-68394, 68416); U.S. National Parasite Collection, Beltsville, USA (USNPC 103438.00 and 103439.00); Zoological Survey of India, Kolkata (Calcutta), India (ZSI).

SITE OF INFECTION: Intestine (worms with immature proglottides attached to the anterior part of the intestine; highly motile gravid proglottides unattached, localized in the lumen of the most posterior part of the intestine).

INFECTION RATE (based on the data from Mukutmanipur, West Bengal, 14 & 15 March 2009): prevalence 83% (5 of 6 fishes examined); mean intensity 7.4 (range 1-15).

REDESCRIPTION (based on 7 specimens from Mukutmanipur dam lake, West Bengal, India): Proteocephalidea, Proteocephalidae, Gangesiinae. Testes, ovary, uterus and vitelline follicles medullary. Worms 15-21 mm long (n = 6) to 170-625 wide. Strobila hyperapolytic consists of 36-47 immature proglottides; mature, pregravid and gravid proglottides detached, living separately. A few first proglottides wider than long, but more developed proglottides always much longer than wide (Figs 14-16).

Scolex 110–115 long (n = 4) by 225-245 wide (n = 4), without metascolex, but with specific rostellum-like structure, 140-155 wide (n = 4), armed with crown consisting of one row of 17-20 large hooks (Figs 1-7, 17); hooks 62-69 long (blade 26-29, handle 37-39, guard 16-17; n = 6) (Figs 19-20). Several rows of "spines" (in fact large coniform spinitriches – Figs 7, 8, 17) 2-3 long (n = 30) present posterior to large hooks. Rostellum-like organ with well developed retractors (Figs 19-20). Suckers spherical, uniloculate, 95-115 in diameter (n = 16), directed laterally, with several rows of giant coniform spinitriches 5-7 long (n = 30) on external rim of suckers (Figs 9, 10, 17). Scolex, including sucker cavities, covered with capilliform filitriches (Figs 11-12). Proliferative zone (region from posterior margin of suckers to ring-like margin delimiting first proglottis) 220-285 long (n = 4) by 130-175 wide, covered with small gladiate spinitriches (Fig. 13).

Inner longitudinal musculature well developed in immature and mature proglottides, anastomosed (Fig. 22), forming wide bundles of muscle fibres (Fig. 23); dorsoventral muscles present. Longitudinal muscle fibres weakly developed in gravid (hyperapolytic) proglottides.

Ventral osmoregulatory canals wide, thin-walled, anastomosed near posterior margin of proglottis (Fig. 15), medial to medioventral to vitelline follicles (Fig. 15). Dorsal osmoregulatory canals thick-walled, narrow, medial to mediodorsal to vitelline follicles; canals lateral to testes (Figs 15, 23).

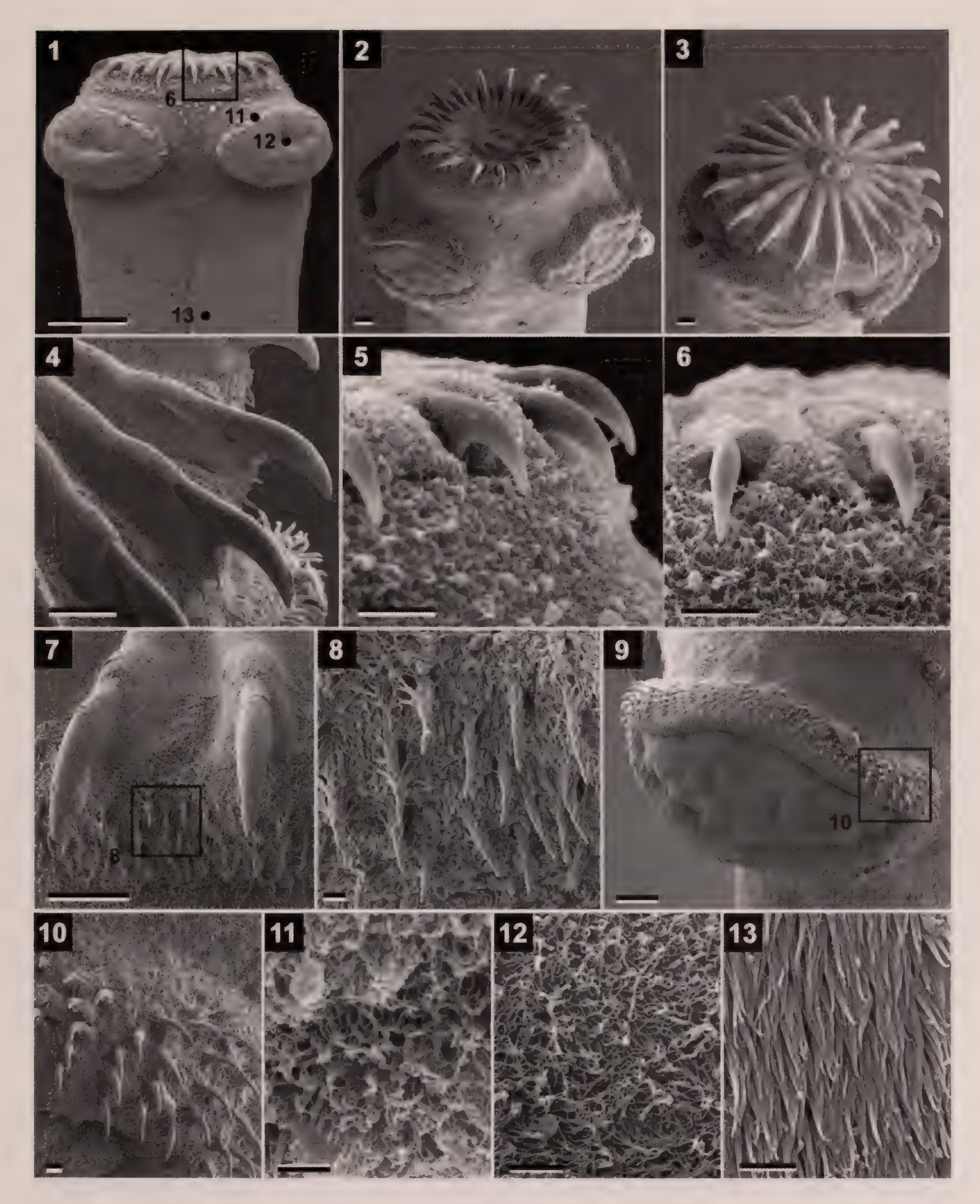
Testes medullary, spherical to oval, 47-56 × 45-53 (n = 30) in size, numbering 110-132 (n = 9), in one irregular layer and two lateral fields (Figs 15, 18, 22). Cirrus-sac elongate to pyriform, gradually narrowing to distal end, thick-walled proximally (Fig. 21), 140-145 long and 45-53 wide, representing about 30-37% of proglottis width (n = 4). Cirrus covered with long spinitriches (Fig. 21). Genital pore situated at 49-57% (n = 14) of proglottis length (Figs 15-16).

Ovary medullary, compact, bilobed, with short and wide lateral lobes connected by ventrally situated isthmus (Fig. 18). Total length of ovary 205-340, representing 9-12% of proglottis length (n = 5); width of ovary 185-255, representing 45-50% (n = 5) of proglottis width. Mehlis' glands between posterior ovarian lobes (Fig. 18), representing 14-17% of proglottis width.

Vagina tubular, sinuous in proximal part, straight, directed anterolateral (oblique) in distal part, posterior to cirrus-sac (Fig. 21), with ampullaceous, thick-walled atrium before vaginal canal enters into common genital atrium (Fig. 21).

Vitellarium medullary, formed by two short lateral bands of follicles in pre-ovarian region, posterior to genital pore (Figs 15, 18); bands of follicles 295-395 long (n = 8), which represents much less than 1/5 (14-18%) of proglottis length (Fig. 15).

Uterus medullary, with development of type 1 according to de Chambrier *et al.* (2004), defined as follows: In immature proglottides, uterine stem present as longitudinal concentration of chromophilic cells along median line (Figs 14, 15). Lumen of uterus appears in last premature proglottides, gradually extending to form tubular structure. Further development occurs as progressive lateral formation of thin-walled diverticula. In detached gravid proglottides, lateral diverticula remain thin-walled, numerous (Fig. 16), sac-like on each side, occupying up to 71% of proglottis width. Detached proglottides highly motile, with uterus containing high number of eggs




FIGS 1-13

*Vermaia pseudotropii* (Verma, 1928). Scanning electron photomicrographs. (1) INVE 68393, scolex, dorsoventral view. (2, 3) IND 387. Scolex, subapical views; note a rostellum-like organ with large hooks. (4-6) INVE 68393, Details of hooks. (7, 8) IPCAS c-566. (IND 387). Capilliform filitriches and large coniform spinitriches posterior to the rostellum-like organ. (9) IPCAS c-566. (IND 387). Suckers with giant coniform spinitriches on the external rim. (10) IPCAS c-566. (IND 387). Detail of the sucker rim with giant coniform spinitriches. (11-13) INVE 68393. (11) Capilliform filitriches and coniform spinitriches on the external rim of suckers. (12) Internal surface of the suckers. (13) Gladiate spinitriches on the proliferative zone. Scale-bars: 1 = 50 $\mu$m; 2-7, 9 = 10 $\mu$m; 8, 10 = 1 $\mu$m; 11-13 = 3 $\mu$m.

filling most space of proglottides. During development of gravid proglottides, genital organs degenerate, vitelline follicles disappearing first, followed by ovary and then testes (Fig. 16). No uterine apertures (uterine pores) observed.

Egg spherical, with hyaline outer membrane 120-130 (n = 25) in diameter (collapsed in permanent mounts) and spherical embryophore 26-31 in diameter (Figs 24-26). Oncospheres spherical to oval, 17-20 in diameter, with 3 pairs of hooks 4-6 (n = 12) long (Figs 25-26).

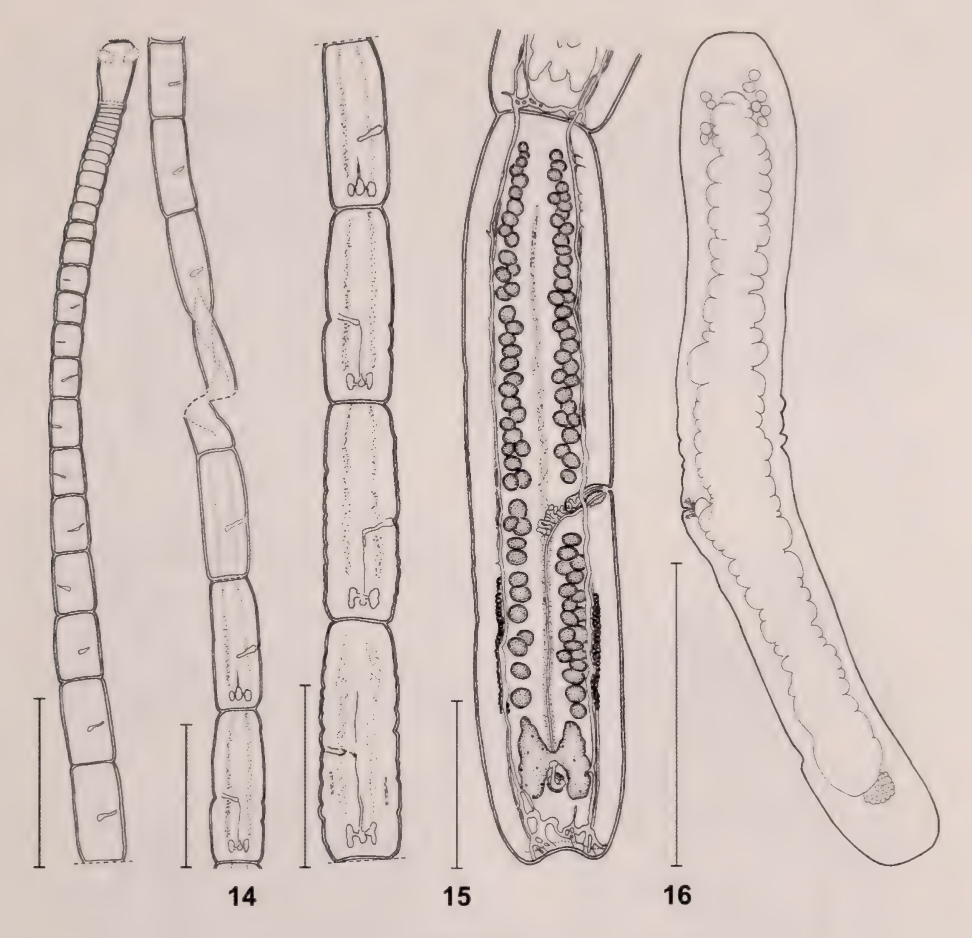
## DISCUSSION

New, well-fixed material of *Vermaia pseudotropii* recently collected in India enabled us to provide new morphological data on this peculiar cestode, which is typified by a number of morphological and biological characteristics, most of them absent in other freshwater fish cestodes: (i) hyperapolysis of the strobila; (ii) presence of a rostellum-like organ armed with one crown of large, robust hooks of typical shape (Figs 1-7, 17, 19, 20); (iii) vitelline follicles limited to a short pair of lateral bands, the length of which represents only about 14-18% of the proglottis length (Figs 15, 18); (iv) presence of an ampullaceous vaginal atrium at the terminal (distal) end of the vaginal canal before it opens into a common genital atrium (Fig. 21); (v) "spined" cirrus, i.e. the cirrus covered with long spinitriches (Fig. 21). Accordingly, Nybelin's (1942) proposal of *Vermaia* as a new genus to accommodate *Gangesia pseudotropii* Verma, 1928 seems to be correct and well justified, because other species of *Gangesia* Woodland, 1924 (and other gangesiine cestodes, too) differ in a number of morphological features and none of them is hyperapolytic.

Hyperapolysis, i.e. release of a proglottis precociously before it contains any eggs in the uterus to complete its development while free in the intestine of the host (see Glossary in Khalil *et al.*, 1994 – p. 683), is a relatively common phenomenon in some tetraphyllidean cestodes, parasites of elasmobranchs (Euzet, 1994). Only two cestodes parasitic in freshwater teleosts have been reported to have hyperapolytic proglottides, namely the nippotaeniid *Amurotaenia percotti* Akhmerov, 1941, a parasite of the Chinese sleeper, *Perccottus glehni* (Perciformes: Odobuntidae), and *V. pseudotropii* (Wardle & McLeod, 1952; Bray, 1994).

The present study, which included for the first time SEM observations, has also revealed some morphological characteristics of *V. pseudotropii* not reported previously: (i) "spines" (large coniform spinitriches) situated posterior to the "rostellar" hooks; (ii) the terminal (distal) part of the vaginal canal is thick-walled and forms a semispherical (ampulla-like) atrium (Fig. 21); such a structure has not been reported in any other proteocephalidean cestode; (iii) eggs are of a "typical" proteocephalidean appearance (see de Chambrier and Vaucher, 1999; Scholz, 1999; Scholz and de Chambrier, 2003; Conn and Świderski, 2008), i.e. the oncosphere is surrounded by an embryophore and outer envelope is hyaline, increasing its size when in water (Figs 24-26); (iv) uterine development, which is described for the first time in this species, corresponds to the type 1 according to de Chambrier *et al.* (2004).

Freze (1965), Schmidt (1986) and Rego (1994) compiled figure 22 of Verma (1928) of an incomplete mature proglottis of *V. pseudotropii*, but they did not recognize that only the posterior part of the proglottis was figured. Therefore, their illustrations

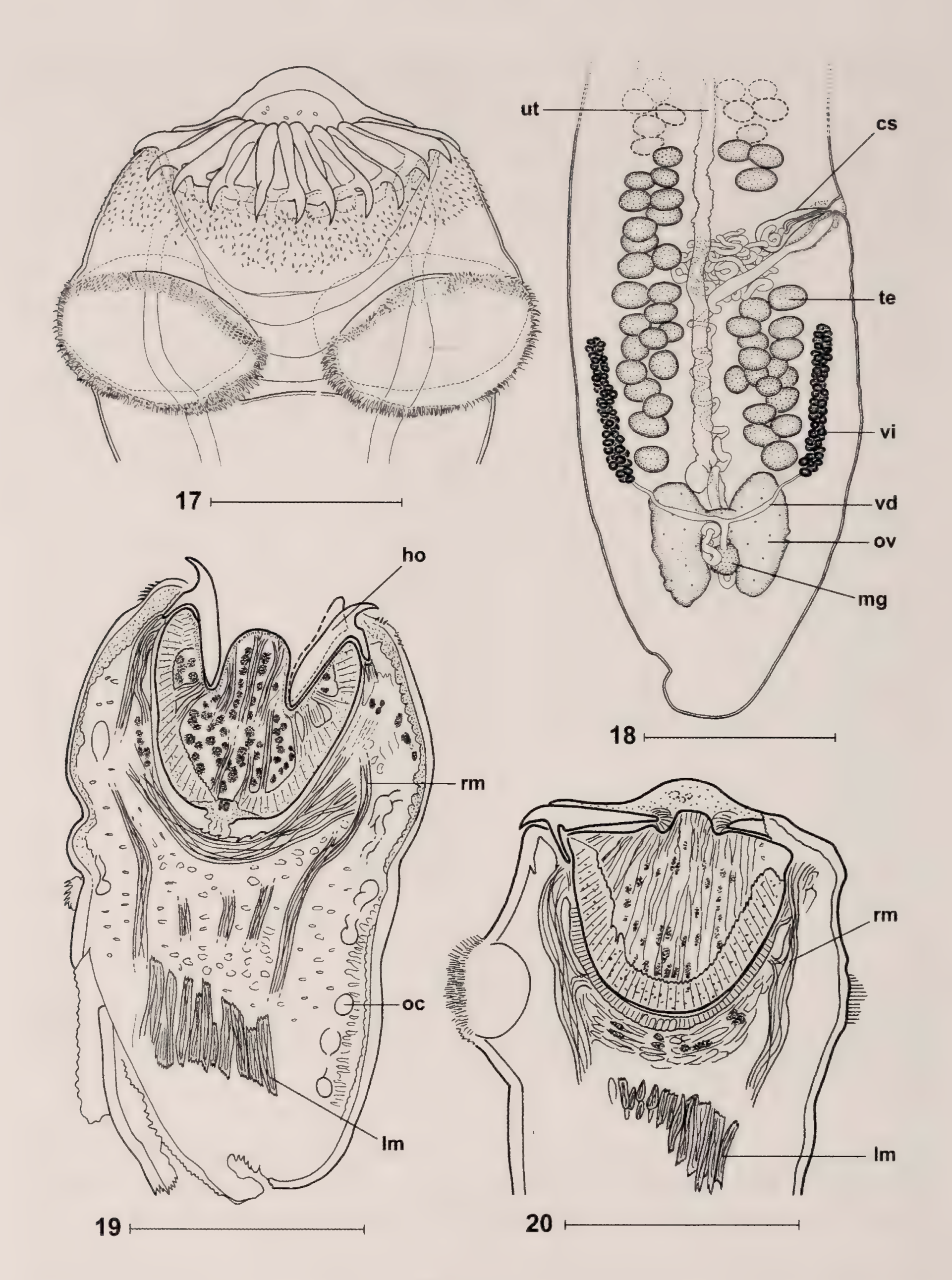



FIGS 14-16

*Vermaia pseudotropii* (Verma, 1928). (14) IPCAS c-566. Total view of immature worms from the anterior part of the intestine. (15) INVE 68394. Mature proglottis, ventral view; note dorsal and ventral excretory canals. (16) INVE 68416. Gravid proglottis, ventral view. Scale-bars: 14, 16 = 1000 $\mu$m; 15 = 500 $\mu$m.

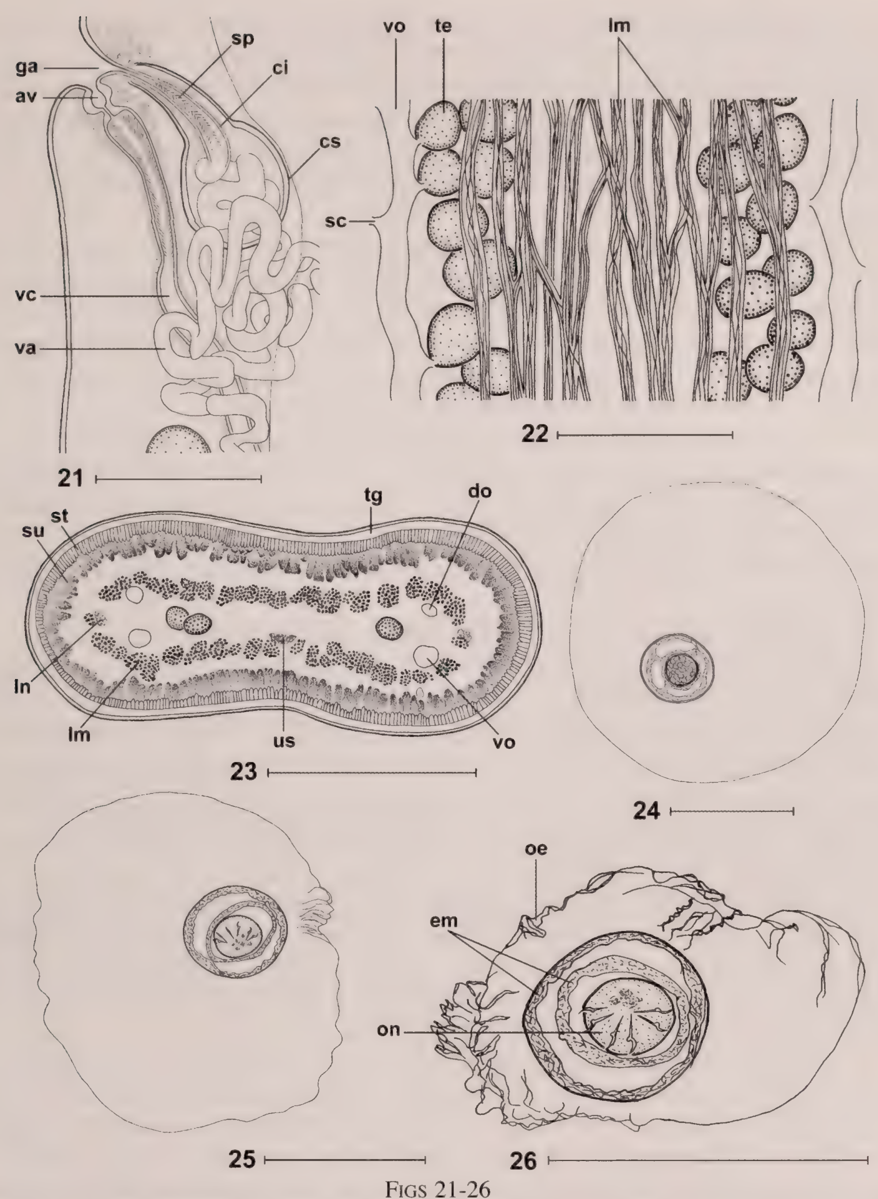
(figure 136g in Freze, 1965, figure 208b in Schmidt, 1986 and figure 13.31 in Rego, 1994) are misleading because they show a genital pore very close to the anterior margin of the proglottis and a significantly underestimated number of testes (Fig. 15 in the present paper).

Verma (1928) reported that some eggs developed to a "cysticercus" stage with a "bladder" already within the uterus of gravid proglottides. He assumed that this may indicate the existence of a direct cycle of the tapeworm. In this study, similar metacestodes, i.e. cysticercus-like larvae, were not observed in any of numerous gravid proglottides. However, collapsed outer hyaline envelopes of eggs, which may have been misinterpreted by Verma (1928) as a "bladder" of "cysticercus" metacestodes, were observed (Fig. 26).




FIGS 17-20

*Vermaia pseudotropii* (Verma, 1928). (17) Scolex, dorso-ventral view. (18) INVE 68416. Posterior part of a pregravid proglottis, ventral view; note very short bands of vitelline follicles. (19) IPCAS c-566. Scolex, sagittal section, rostellum-like organ slightly invaginated. (20) INVE 68394. Scolex, sagittal section, rostellum-like organ slightly evaginated. *Abbreviations*: *cs* cirrus-sac, *oc* osmoregulatory canal, *ho* hooks, *lm* internal longitudinal musculature, *mg* Mehlis' glands, *ov* ovary, *rm* retractor muscles, *te* testes, *ut* uterus, *vd* vitelloduct, *vi* vitelline follicles. Scale-bars: 17, 19-20 = 100 $\mu$m; 18 = 500 $\mu$m.




FIGS 21-26

*Vermaia pseudotropii* (Verma, 1928). (21) INVE 68416. Terminal genitalia; note a muscular, ampullaceous vaginal atrium. (22) IPCAS C-566. Inner longitudinal musculature. (23) BMNH 2010.7.26.2-3. Cross section of an immature proglottis. (24-26) IPCAS C-566. Eggs; note developing oncosphere without embryonic hooks in 24 and fully formed oncosphere with embryonic hooks in 25 & 26 and a partly collapsed outer envelope in 26. *Abbreviations*: *av* ampullaceous vaginal atrium, *ci* cirrus, *cs* cirrus-sac, *do* dorsal osmoregulatory canal, *em* bilayered embryophore, *ga* genital atrium, *lm* internal longitudinal musculature, *ln* longitudinal nerve, *oe* outer envelope, *on* oncosphere, *sc* secondary canal, *su* subtegumental cells, *sp* spinitriches on cirrus, *st* subtegumental muscles, *tg* tegument, *te* testes, *us* uterine stem, *va* vas deferens, *vc* vaginal canal, *vo* ventral osmoregulatory canal. Scale-bars: 21-23 = 100 $\mu$m; 24-26 = 50 $\mu$m.

No uterine aperture was observed in last gravid proglottides. It is therefore possible that ripe eggs are released from these proglottides after their desintegration due to autolysis. This assumption is supported by the fact that the musculature is very weakly developed in these proglottides and genital organs are disappearing, with vitelline follicles desintegrated first, followed by the ovary and testes (Fig. 16). The parenchyma of these proglottides also desintegrates and the internal tissues have loose structure.

In the generic diagnosis of *Vermaia*, Rego (1994 – p. 273) described the longitudinal musculature to be weak, but this information is misleading because inner longitudinal muscles are in fact very well developed in immature and mature proglottides, being formed by large bundles of muscle fibres (Fig. 23). However, the inner longitudinal musculature of hyperapolytic gravid proglottides is weakly developed and is formed by a narrow band of loose, widely separated fibres (Freze, 1965).

In addition to *V. pseudotropii*, two other species have been placed in *Vermaia*: *V. jammuensis* (Fotedar & Dhar, 1974) and *V. sorrakowahi* Zaidi & Khan, 1976 (Fotedar & Dhar, 1974; Zaidi & Khan, 1976). The former species was briefly described as *Gangesia* (*Vermaia*) *jammuensis* from *Wallago attu* (Bloch & Schneider, 1801) from Jammu in India, but this description was presented in an abstract from a regional congress only.

The same authors (Dhar & Fotedar, 1980) proposed division of *Gangesia* to two subgenera, *Gangesia* and *Vermaia*, the latter one being characteristic by regularly alternate genital pores. However, this characteristic is actually absent in the type species of *Vermaia*, *V. pseudotropii*, because genital pores alternate irregularly (e.g. LRLRLLRLRRR in Fig. 14). Dhar & Fotedar (1980) placed *Gangesia jammuensis* Fotedar & Dhar, 1974 in this subgenus, but they wrote on p. 118 “The present form is therefore, considered here to constitute a new species for which the name *Gangesia* (*Vermaia*) *jammuensis* is proposed.”

In fact, this name was already published in 1974 and must not be considered as a new species in the paper of Dhar & Fotedar (1980). Moreover, tapeworms designated as *G. jammuensis* are conspecific with *Gangesia agraensis* Verma, 1928, a specific parasite of *W. attu*, as obvious from morphological similarity of both species (Verma, 1928; Dhar & Fotedar, 1980; unpublished data).

Zaidi & Khan (1976) described another species of *Vermaia*, *V. sorrakowahi*, from the shark *Scoliodon sorrakowah* (Cuvier, 1817) (= *Scoliodon laticaudus* Müller & Henle, 1838), from the Arabic Sea off Pakistan. The finding of a proteocephalidean cestode in a shark seems to be accidental, but *V. sorrakowahi* differs from *V. pseudotropii* in a number of morphological characteristics: (i) the distribution of vitelline follicles, which form two long lateral bands alongside the most length of proglottis, i.e. from the anterior margin of the proglottis to the preovarian level (see figure 15c in Zaidi & Khan, 1976), whereas the vitellarium is limited to much less than 1/5 of the proglottis length in *V. pseudotropii* (Fig. 15); (ii) the pre-equatorial position of the cirrus-sac (versus postequatorial in *V. pseudotropii*); (iii) total length of the body (5-6 mm versus 15-21 mm in *V. pseudotropii*); (iv) the number (28 versus 17-20) and size (99-124 $\mu$m versus 62-69 $\mu$m) of hooks on the rostellum-like organ; and (v) the number of testes (60-70 versus 110-132) (Zaidi & Khan, 1976; present study).

Shinde & Wankhede (1990) described *Gangesia sumani* from *Mastacembelus armatus* from Aurangabad, Maharashtra, India, but this description was incomplete and just two schematic illustrations of the scolex and a mature proglottis were provided. This species was differentiated from 4 species of *Gangesia* Woodland, 1924, including *G. pseudotropii* (= *Vermaia pseudotropii*), by a few, vague characteristics that were not specified in detail in the description of *G. sumani* or were even absent in the text (the number of hooks and the structure of vas deferens). In fact, it is obvious from this poor description and both figures, altough schematic and incomplete, that *G. sumani* is identical with *V. pseudotropii*, especially because of the unique distribution of vitelline follicles, which are limited to the preovarian region posterior to the cirrus-sac, by the presence of a rostellum-like organ armed with large hooks, elongate mature proglottides, and testes arranged in one longitudinal band on each side of the body (compare Figs 15, 17, 19-20 with fig. 2B in Shinde and Wankhede, 1990).

The present authors (A. A., T. S. and P. K. K.) and their co-workers (M. Oros) examined 44 *M. armatus* from eight localities in three Indian states, including Aurangabad in Maharashtra, the type-locality of *G. sumani*, but they never found any proteocephalidean cestode. It is very probable that the finding of *V. pseudotropii* in this predatory fish was an accidental infection; mislabelling of samples could be another explanation of this unusual report.

Based on the data summarized in this paper, *Vermaia* consists of 2 species, *V. pseudotropii* (type-species) and *V. sorrakowahi*, but the definitive host of the latter species is questionable and new material should be collected for a more detailed morphological and genetic characterization of this taxon.

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## REFERENCES

BRAY, R. A. 1994. Nippotaeniidea Yamaguti, 1939. (pp. 253-255) In: KHALIL, L. F., JONES, A. & BRAY, R. A. (eds) *Keys to the cestode parasites of vertebrates*, Wallingford: CAB International: 751 pp.

DE CHAMBRIER, A., AL KALLAK, S. N. H. & MARIAUX, J. 2003. A new tapeworm *Postgangesia inarmata* sp. n. (Eucestoda: Proteocephalidea: Gangesiinae), parasite of *Silurus glanis* (Siluriformes) from Iraq and some considerations on Gangesiinae. *Systematic Parasitology* 55: 199-209.

DE CHAMBRIER, A. & VAUCHER, C. 1999. Proteocephalidae et Monticelliidae (Eucestoda: Proteocephalidea) parasites de poissons d'eau douce du Paraguay avec descriptions d'un genre nouveau et de dix espè ces nouvelles. *Revue suisse de Zoologie* 106(1): 165-240.

DE CHAMBRIER, A., ZEHNDER, M., VAUCHER, C. & MARIAUX, J. 2004. The evolution of the Proteocephalidea (Platyhelminthes, Eucestoda) based on an enlarged molecular phylogeny, with comments on their uterine development. *Systematic Parasitology* 57: 159-171.

CHERVY, L. 2009. Unified terminology for cestode microtriches: a proposal from the International Workshop on Cestode Systematics in 2002–2008. *Folia Parasitologica* 56: 199-230.

CONN, D. B. & ŚWIDERSKI, Z. 2008. A standardised terminology of the embryonic envelopes and associated developmental stages of tapeworms (Platyhelminthes: Cestoda). *Folia Parasitologica* 55: 42-52.

DHAR, R. L. & FOTEDAR, D. N. 1980. Some proteocephalid cestodes in freshwater fishes of Jammu & Kashmir. *Indian Journal of Helminthology* 31: 111-127.

EUZET, L. 1994. Order Tetraphyllidea Carus, 1863. (pp. 149-194) *In*: KHALIL, L. F., JONES, A. & BRAY, R. A. (eds) *Keys to the cestode parasites of vertebrates*, Wallingford: CAB International: 751 pp.

FOTEDAR, D. N. & DHAR, R. L. 1974. *Gangesia* (*Vermaia*) *jammuensis* n. sp. (Proteocephalidae: Cestoda) from a freshwater fish in Jammu, India. Proceedings of the 11th Session of the Indian Section Long. Nagpur, 38 pp.

FREZE, V. I. 1965. *Essentials of Cestodology*. Vol. V. *Proteocephalata in Fish, Amphibians and Reptiles*. Moskva: Izdatel'stvo "Nauka", 538 pp. (In Russian: English translation, Israel Program of Scientific Translation, 1969, Cat. No. 1853. v + 597 pp)

FROESE, R. & PAULY, D. 2010. FishBase.*World Wide Web electronic publication*. www.fishbase.org, version (01/2010), Froese & Pauly Editors.

KHALIL, L. F., JONES, A. & BRAY, R. A. (eds) *Keys to the cestode parasites of vertebrates*, Wallingford: CAB International: 751 pp.

NYBELIN, O. 1942. Zur Helminthen Fauna der Süsswasserfische Schwedens. II. *Die Cestodes des Welses. Göteborgs Kungl. Vetenkaps Och Vitterhets-samhalles Handlingar, Series* B1: 1-24.

OROS, M., SCHOLZ, T., HANZELOVÁ, V., MACKIEWICZ, J. S. 2010. Scolex morphology of monozoic cestodes (Caryophyllidea) from the Palaearctic Region: a useful tool for species identification. *Folia Parasitologica* 57: 37-46.

REGO, A. A. 1994. Order Proteocephalidea Mola, 1928. (pp. 257-293) *In*: KHALIL, L. F., JONES, A. & BRAY, R. A. (eds) *Keys to the cestode parasites of vertebrates*, Wallingford: CAB International: 751 pp.

SCHMIDT, G. D. 1986. *CRC Handbook of tapeworm identification*. Boca Raton: CRC Press: 675 pp.

SCHOLZ, T. 1999. Life cycles of species of *Proteocephalus*, parasites of fishes in the Paleartic Region: a review. *Journal of Helminthology* 73: 1-18.

SCHOLZ, T. & DE CHAMBRIER, A. 2003. Taxonomy and biology of proteocephalidean cestodes: current state and perspectives. *Helminthologia* 40: 65-77.

SCHOLZ, T & HANZELOVÁ, V. 1998. Tapeworms of the genus *Proteocephalus* Weinland, 1858 (Cestoda: Proteocephalidae), parasites of fishes in Europe. *Studie AV ČR*, No. 2/98, Academia, Praha, 119 pp.

SHINDE, G. B. & WANKHEDE, J. 1990. Two new species of the genus *Gangesia* Woodland, 1924 (Cestoda: Proteocephalidea). *Indian Journal of Parasitology* 14: 141-143.

VERMA, S. C. 1928. Some cestodes from Indian fishes, including four new species of Tetraphyllidea and revised keys to the genera *Acanthobothrium* and *Gangesia*. *Allahabad University Studies* 4: 119-176.

WARDLE, R. A., MCLEOD, J. A. 1952. *The zoology of tapeworms*. The University of Minnesota Press, Minneapolis: 750 pp.

YAMAGUTI, S. 1959. *Systema Helminthum. Vol II. The cestodes of vertebrates*. New York & London: Interscience Publishers, Inc.: 860 pp.

ZAIDI, D. A. & KHAN, D. 1976. Cestodes of fishes from Pakistan. *Biologia Lahore* 22: 157-179.

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# First description of larval and juvenile stages of *Rhacophorus maximus* Günther, 1859 "1858" (Anura: Rhacophoridae) from Vietnam

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**First description of larval and juvenile stages of *Rhacophorus maximus* Günther, 1859 "1858" (Anura: Rhacophoridae) from Vietnam. -** We describe the tadpole morphology of the Nepal flying frog, *Rhacophorus maximus* Günther, 1859 "1858", based on specimens originating from the lowland evergreen forest of the Tay Yen Tu Nature Reserve in the Bac Giang Province in northern Vietnam. The description is based on exotrophic larvae of ORTON's type IV: lentic, benthic, nektonic in developmental stages 33-41, which were bred at the IEBR Amphibian Breeding Station in Hanoi and identified by DNA barcoding. DNA sequences of the mitochondrial 16S rRNA gene obtained from a tadpole voucher in developmental stage 35 used for the description had less than 0.18% sequence divergence to those of a sympatric adult frog, making the identification unambiguous. Tadpoles of *R. maximus* are of more generalized morphology with a labial tooth row formula of 5(2-5)/3(1). In addition, based on (hand-) reared froglets and by identifying wild-caught subadults through DNA barcoding, we provide first data on colour pattern change from metamorphosed to adult stages.

**Keywords:** Rhacophoridae - *Rhacophorus maximus* - DNA barcoding - tadpole - morphology - development - colour pattern change - Vietnam.

## INTRODUCTION

The investigation of amphibian diversity in Vietnam strongly increased in recent decades. Only in the past six years, 26 Vietnamese anuran species have been discovered (Nguyen *et al.*, 2009). However, in contrast to the increasing richness of amphibian species, many of them are only known from a few specimens preserved in

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museums and virtually nothing is known about the natural history of adults and in particular of their larval stages. The knowledge of larval adaptations is inadequate or often completely lacking up to this date, but it is a crucial prerequisite for adequate amphibian conservation measures. This deficiency is due to the fact that detailed morphological larval descriptions are still lacking for many species, e.g. the tree frog *Rhacophorus maximus*.

*R. maximus* was described by Günther (1859 "1858") from the type locality "Nepal". The Nepal flying frog is generally characterized by its large size, bright green dorsal colouration in combination with a narrow white flank stripe, and complete webbing between fingers and toes (Anders & Rai, 2002). The crepuscular species inhabits the canopy of lowland to submontane moist evergreen forest. Its distribution ranges from North-Eastern India to Southern China, Western Thailand and Northern Bangladesh (Frost, 2009). Orlov *et al.* (2008) mentioned the species' presence in Vietnam, but did not provide specimen-based, specific locality records. Only recently, Nguyen *et al.* (2008) provided a first detailed record of *R. maximus* from Vietnam, namely from the Tay Yen Tu Nature Reserve in the Bac Giang Province (Figs 1-2), which is part of the largest continuous area of lowland evergreen forest in north-eastern Vietnam (Birdlife International, 2004). As this type of forest has been cut down in most other areas of north-eastern Vietnam, this region is expected to house a unique biodiversity that is no longer found elsewhere in the country. According to the IUCN Red List of threatened species the status of *R. maximus* is least concern and the population trend is decreasing.

The knowledge of the larval stages of *Rhacophorus maximus* is poor. Sinha *et al.* (2001) conducted food spectrum analyses based on tadpoles of *R. maximus* from India, and Khongwir *et al.* (2003) studied metamorphosis and the development of the mouth region. Drawings of tadpoles from Nepal in an obviously early developmental stage were published by Anders & Rai (2002), who also dealt with the advertisement call of the species. However, no comprehensive descriptions on the larval morphology of *R. maximus* are available.

Thus, the object of this paper is to provide a first detailed description of the larval morphology of *R. maximus* from Vietnam. This description is based on larvae originating from adult frogs from the Tay Yen Tu Nature Reserve. In addition, based on froglets (reared by us) together with wild-caught subadults from the Tay Yen Tu Nature Reserve partly identified by DNA barcoding, we also describe for the first time colour pattern change from metamorphosed individuals towards adult stages.

## MATERIAL AND METHODS

A series of larvae, juveniles, subadults, and adults of *Rhacophorus maximus* from the Tay Yen Tu Nature Reserve, Bạc Giang Province, northern Vietnam were used for the following descriptions. Adults identified by size and gonad development were collected in the field; larval, juvenile and subadult stages derived from successful breeding of *R. maximus* from Tay Yen Tu at the Amphibian Breeding Station of the Institute of Ecology and Biological Resources in Hanoi. We used fresh dead specimens for the morphological descriptions, fixed in 40-70% ethanol, preserved in 70% ethanol and subsequently deposited in the following museums: IEBR = Institute of Ecology




FIG. 1
Location (large dot) of the Tay Yen Tu Nature Reserve, Bac Giang Province, North-Eastern Vietnam, the so far only known record of *Rhacophorus maximus* from Vietnam.

and Biological Resources, Hanoi, Vietnam; MHNG = Muséum d'histoire naturelle, Geneva, Switzerland; VNMN = Vietnam National Museum of Nature, Hanoi, Vietnam; ZFMK = Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany.

Specific vouchers were used as follows: adult: IEBR 3653; subadults: IEBR A.0940, MHNG 2721.50, VNMN 1211, ZFMK 89786; juveniles: MHNG 2721.51, VNMN 1212, ZFMK 89787-89788; froglets: IEBR A.0941, MHNG 2721.52, ZFMK 89790; tadpoles: IEBR A.0942, MHNG 2721.53, VNMN 1214, ZFMK 89791-89792. The colour pattern was studied in juvenile, subadult, and adult stages currently kept at the Amphibian Breeding Station at Hanoi, at the Aquarium of the Cologne Zoo, and on wild-caught specimens from Tay Yen Tu, which were released subsequently.

Several studies have demonstrated that DNA barcoding, especially when using the mitochondrial 16S rRNA gene, is a reliable identification tool in amphibian taxonomy (e.g., Vences *et al.*, 2005; Bwong *et al.*, 2009). We used this method to unambiguously assign specific vouchers to *R. maximus*. For the assignment of the tadpoles of *R. maximus*, molecular data were obtained for a larva in Gosner stage 35 (IEBR A.0942; GenBank accession number HM448032), which also served for the larval description and illustration (with a partly removed tail muscle tissue due to the taken tissue sample). We compared the resulting sequence with homologous DNA fragments of a syntopic, adult *R. maximus* (IEBR 3653; GenBank accession number HM448031; see also Nguyen *et al.* 2008). We also compared DNA fragments of this adult specimen with a subadult specimen collected in Tay Yen Tu (IEBR A.0940; GenBank accession number HM448030), having a divergent colour pattern, so far not recorded for *R. maximus*. DNA was extracted using the peqGold Tissue DNA Mini Kit (PEQLAB Biotechnologie GmbH). The primers 16sar-L (light chain; 5' – CGC CTG TTT ATC AAA AAC AT – 3') and 16sbr-H (heavy chain; 5' – CCG GTC TGA ACT CAG ATC ACG T – 3') of Palumbi *et al.* (1991) were used to amplify a section of the mitochondrial 16S ribosomal RNA gene (569 bp). PCR cycling procedure followed Schmitz *et al.* (2005). PCR products were purified using QIAquick purification kits (Qiagen). Sequences (including complimentary strands for ensuring the accuracy of the sequences) were obtained using an automatic sequencer (ABI 377). Sequences were examined and aligned manually using the original chromatograph data in the program BioEdit (Hall, 1999). The same program was used to calculate the direct pairwise similarities for the resulting sequences.

The terminology for adult, subadult, and juvenile stages followed Manthey & Grossmann (1997) and Glaw & Vences (1994). The tadpole terminology, morphometrics and abbreviations (partly modified) followed Altig & McDiarmid (1999) and Grosjean (2005), the labial tooth row formula (LTRF) was determined according to Altig & McDiarmid (1999), and the keratodont row formula (KRF) according to Dubois (1995); for general larval types see Orton (1953). Determination of larval stages was set out according to Gosner (1960). Colouration in life of all specimens was described by means of photographs.

Abbreviations used for morphological descriptions are as follows. *Adults, subadults, juveniles*: SVL = snout-vent length; HW = maximum head width; HL = head length, from tip of snout to end of lower jaw; EN = distance between anterior angle of eye to centre of nostril; NS = distance between centre of nostril to tip of snout; ED =



FIG. 2

Habitat of *Rhacophorus maximus* in the Tay Yen Tu Nature Reserve, Bac Giang Province, northeastern Vietnam. Photograph by T. Ziegler.

horizontal diameter of eye; TD = horizontal diameter of tympanum; FLL = length of fore limb, up to the tip of the longest (third) finger; HLL = length of the extended hind limb from cloaca to tip of longest toe; FL = length of foot, exclusive of tarsus, from base of inner metatarsal tubercle up to tip of longest (fourth) toe; IMT = length of inner metatarsal tubercle.

*Larvae*: BH = body height (midpoint of body); BL = body length ; BW = body width (midpoint of body); ED = maximum diameter of eye (horizontal); IP = interpupilar distance (from midpoint of eyes); IND = internarial distance; NPD = naropupilar distance; RND = rostro-narial distance (from tip of snout); SP = snout-pupil distance; ODW = oral disc width; NK = number of keratodonts (per 0.5 mm of the A3 keratodont row); NP = number of papillae around mouth; SS = snout-spiracle distance (to opening of spiracle); TL = total length; TAL = tail length (from beginning of ventral tube); TMH = height of tail musculature at base; TMW = width of tail musculature at base; UF = height of upper tail fin (midpoint of tail); LF = height of lower tail fin (midpoint of tail); MTH = total tail height (midpoint of tail). All measurements are approximate values and were taken in millimetres (mm) with a digital calliper gauge.

## RESULTS

### LARVAL IDENTIFICATION OF *RHACOPHORUS MAXIMUS* FROM VIETNAM

An unambiguous assignment of a tadpole in stage 35 (IEBR A.0942), which served for the description of the external morphology, to the species *R. maximus* was guaranteed by its negligible 16S sequence divergence (0.18%, corresponding to only single base pair difference) to a sympatric, adult specimen (IEBR 3653).

The adult male IEBR 3653 largely agreed with the descriptions of *Rhacophorus maximus* provided by Günther (1859 "1858"), Boulenger (1890), Bourret (1942), Fei (1999), Yang *et al.* (1991), Anders & Rai (2002), and Nguyen *et al.* (2008): dorsum in life is uniformly green and the venter is fawn; dorsum in preservative is blue to violet and the venter is light brown; in life as well as in preservative a narrow white stripe runs along the flanks; nares are equidistant from the eye and the tip of snout; supra-tympanic fold is distinct; fingers and toes are completely webbed; vomerine teeth are present, as are the vocal sacs; the interorbital distance is distinctly wider than the upper eyelid; the metacarpal tubercle is especially well developed in males; SVL of IEBR 3653 is 104.4 mm (SVL of the type specimen is 92.9 mm according to Günther, 1859 "1858", the maximum SVL is 114.3 mm according to Boulenger, 1890); FLL of IEBR 3653 is 57.5 mm, and HLL is 141.0 mm.

TADPOLE DESCRIPTION

*Colour pattern in preservative*: Body colour is yellow to fawn, dorsally covered with stellate, dense grey to brown pigments, with pigmentation strongest above the nares. The body sides and the venter are only slightly pigmented. Venter is slightly transparent and white to fawn at the region of the intestinal coils. Hind limbs are yellow to white, dorsally covered with dark grey to black pigments. The tail muscu - lature is yellowish-cream with grey pigmentation fading toward the tip. The V-shaped myosepta, the base of the upper fin at the first half of the tail, and the very tip of the tail are much more densely pigmented. The upper and lower tail fins are whitish-cream, slightly transparent with regular grey nodular pigments.

*Colouration in life*: Body colour is yellow to white, slightly transparent and blotched with golden pigments. Dark greyish pigments on the back are strongest at the nares, above the nostrils and eyes. The intestinal coil is well visible laterally and ventrally. The body venter is blotched with silver pigments. The upper and lower tail fins are transparent. The tail is marbled with dark grey and irregular golden pigments. The whitish yellow tail musculature colouration fades towards the tip (Fig. 3B).

*Description in dorsal view*: The body shape is oval-elongated (body width 0.51 of body length) with a pointed to angled snout. Eyes are of moderate size (maximum diameter of eye 0.12 of body length), dorsolaterally positioned and directed at the end of the first third of the body (snout-pupilar distance is 0.29 of body length). The inter-pupilar distance is 0.63 of the body width. Nares are slightly kidney-shaped, anterio-dorsally positioned and laterally directed (rostro-narial distance is 0.64 of naro-pupilar distance). The internarial distance is 0.55 of the interpupilar distance. Spiracle is sinistral and visible. The tadpole has a well developed lateral line organ. On both sides of the head, a line is running from the tip of snout laterally to below the eye, a second line is running from the tip of snout dorsally passing the nare at the inner side and ending dorsally with the eye. The bulge of the oral disc is visible. The tail musculature is of moderate size (width of tail musculature at base is 0.35 of body width) (Fig. 4).

*Description in lateral view*: Body is slightly depressed (body height is 0.80 of body width). Spiracle is sinistral, laterally positioned at the end of the second third of body (distance of snout tip to opening of spiracle is 0.67 of the body length). The spiracle opening is relatively large, rounded, and directed dorsally. Spiracle is attached to the body wall. The lateral line organ is visible and stretches from below the snout to

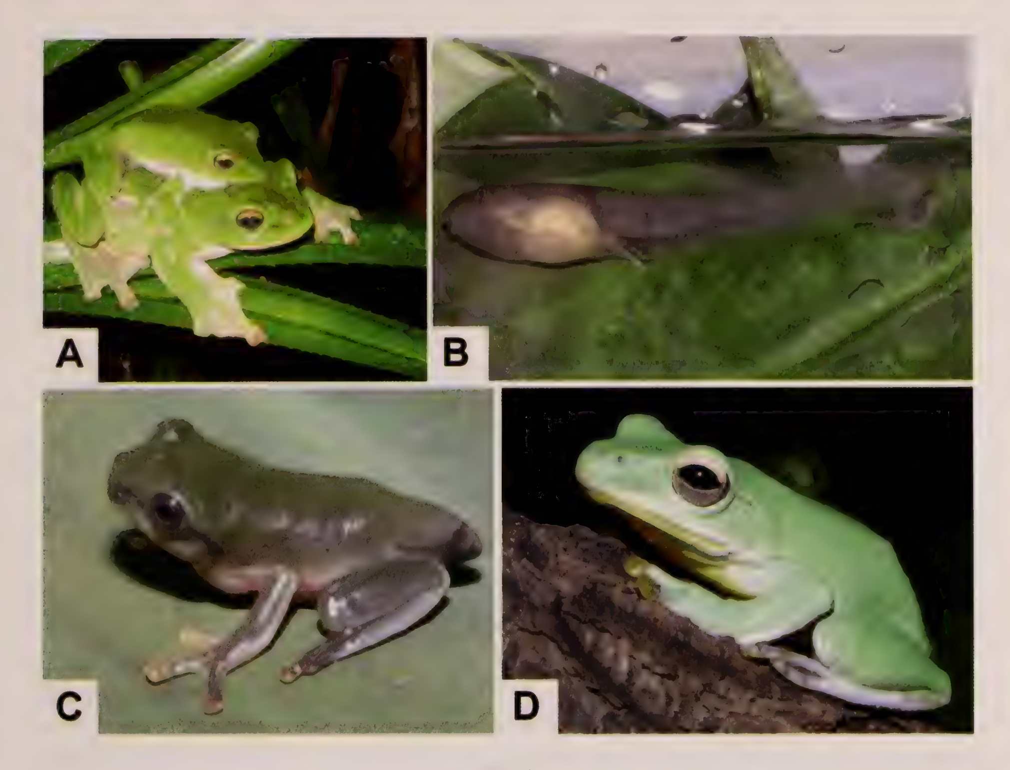



FIG. 3

*Rhacophorus maximus*: (A) Adult, in amplexus, in life in the Tay Yen Tu Nature Reserve, Bac Giang Province, north-eastern Vietnam. (B) Tadpole and (C) Froglet in life at the Amphibian Breeding Station in Hanoi, Vietnam. (D) Juvenile in the terrarium at the Cologne Zoo. Photographs by T. Q. Nguyen (A) and T. Ziegler (B-D).

behind the eyes. The lower lip has marginal papillae sticking out ventrally at the anterior body. The tail length is 1.99 of the body length. The tail musculature is remarkably developed (height of tail musculature at base is 0.64 of body height and 0.61 of maximum tail height) and is more or less equal in height until the second third of the tail before gradually tapering to the tail tip. The upper fin originates at the end of body, it is gradually elevated until midpoint of the tail before tapering until tip of tail (height of upper fin is 0.27 of maximum tail height). The lower tail fin height is constant from base to tip and it is 0.95 of the height of the upper fin at midpoint. Vent tube of IEBR A.0942 is damaged and hence could not be used for description. Therefore, description of vent tube is based on the specimen MHNG 2721.53. It starts ventromedially and fades to the right side in dorsal view, with the opening being remarkably large and elongated. The inner wall is adnated to the lower fin (Fig. 4).

*Oral disc*: Oral disc is positioned anteroventrally and laterally slightly emarginated (oral disc width is 0.41 of body width). It is framed by marginal, rounded papillae, except for a large medial gap at the upper labium and a very small medial gap at the lower labium. All papillae are of moderate size and are white to transparent. Papillae of the upper labium and medial region show pigmentation whereas papillae of

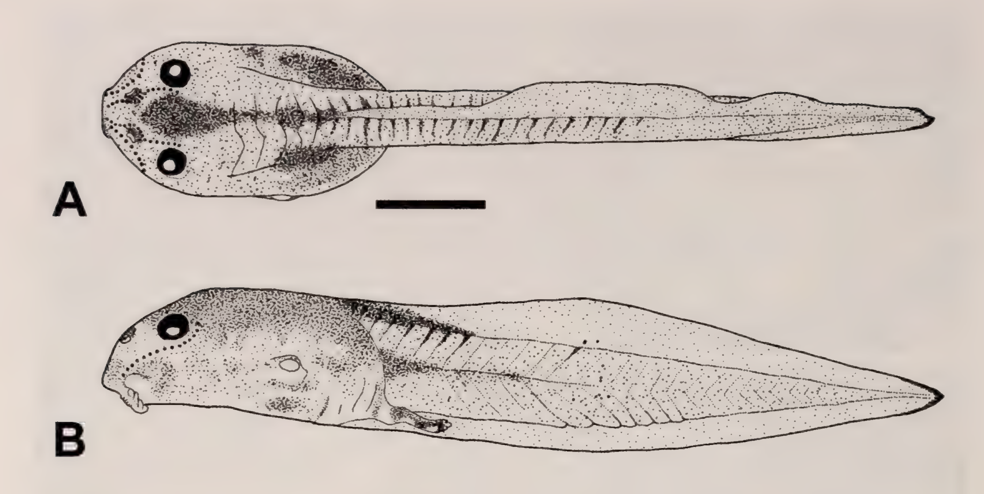



FIG. 4

Drawings of the preserved tadpole of *Rhacophorus maximus* (IEBR A.0942) at Gosner stage 35 (scale bar = 5 mm). (A) dorsal view. (B) lateral view. Drawings by M. J. Wildenhues.

the lower labium lack any pigmentation. The lower labium has one row of submarginal papillae on the right side and two rows of submarginal papillae on the left side. Three separated submarginal papillae are situated left from ventral view. The upper labium has 4-5 submarginal papillae on each side. The oral disc shows 106 papillae in total. The LTRF is 5(2-5)/3(1) and the KRF is 1:4+4/1+1:2 with 35 keratodonts per 0.5 mm of keratodont row A3. Jaw sheaths are dark brown and serrated, except for the lateral endings of the upper jaw sheath. The upper jaw sheath is curved and with long appendices. The lower jaw sheath is V-shaped (Fig. 5).

The specimens MHNG 2721.53, VNMN 1214, and ZFMK 89791-89792, largely correspond to this description (see Table 1 for specific measurements), as do other tadpoles that were only photographed at the Amphibian Station, except for slight variation in the oral disc region (LTRF, KRF, NK, and NP).

## DESCRIPTION OF JUVENILE AND SUBADULT STAGES OF *RHACOPHORUS MAXIMUS* FROM VIETNAM

*Freshly metamorphosed froglets (n = 3; SVL 16.8-19.0 mm)*: The following description is based on specimen IEBR A.0941 (SVL 19 mm) in stage 46.

In preservative, the dorsum is dark grey to dark brown, with black posterior. The ventral side is fawn to yellow with single pigments on the lower jaw. The dorsal surface of fore and hind limbs is covered with grey to brown pigments and the venter is fawn to yellow. The inner sides of feet and hands are slightly dark pigmented. Colouration of the back fades to colouration of the belly.

In life, back is green with somewhat violet pigmentation, more distinct on the lateral side of the tail stub, around the nares, and above the tympanum. The green region fades to fawn before fading to white on the venter. Fore limbs and hind limbs

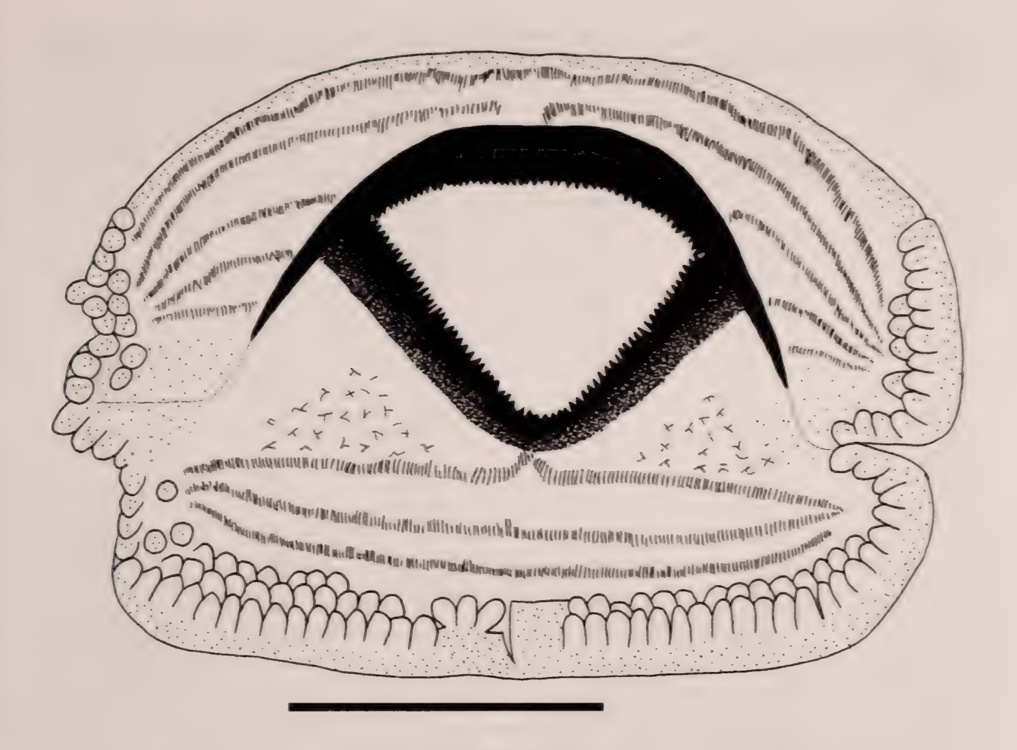


FIG. 5

Oral disc (scale bar = 1mm) of the preserved tadpole of *Rhacophorus maximus* (IEBR A.0942) at Gosner stage 35. Drawing by M. J. Wildenhues.

are green to violet dorsally, and fawn to yellow below. Webbings and discs are yellowish (Fig. 3C).

Body is elongated; head is wider than long (head length is 0.28 and head width 0.39 of total length); snout is rounded and slightly angular at the nostrils; eyes are very large (eye diameter is 0.58 of head length), pupil is round, with a dark line running from the eye towards the lateral end of the head; tympanum is not visible; nostrils are closer to the eye than to the tip of the snout; vomerine teeth and vocal sacs are indistinct.

Fore limbs are moderate (fore limb length is 0.62 of total length); the relative length of fingers is as follows: I < II < IV < III, with rounded to truncate discs, enlarged except for finger I; palmar tubercle and subarticular tubercles are present; webbing is present, webbing formula: I1/2 – 1/2II1/2 –1/2 III 1/2 – 1/2 IV.

Hind limbs are relatively long (length of hind limb is 1.2 of total length); the relative length of toes is as follows: I < II < III = V < IV, with rounded discs; inner metatarsal and subarticular tubercles are present; at the knee and at the tibio-tarsal joint there is a slightly pointed projection; toes are almost fully webbed except for toe IV.

Specimens ZFMK 89790 and MHNG 2721.52 (SVL 16.8-17.5 mm) largely correspond to this description (see Table 2 for measurements), as do other froglets that were only photographed at the Amphibian Station, except for nostrils being closer to

TAB. 1: Measurements (in mm) of the tadpoles of *Rhacophorus maximus* from the Tay Yen Tu Nature Reserve, Bac Giang Province, North-Eastern Vietnam; for abbreviations see material and methods.

| | MHNG 2721.53 | ZFMK 89791 | IEBR A.0942 | VNMN 1214 | ZFMK 89792 |
|---|---|---|---|---|---|
| stage | 33 | 34/35 | 35 | 40/41 | 41 |
| BH | 5.2 | 5.2 | 5.4 | 5.9 | 6.4 |
| BL | 11.9 | 12.1 | 13.1 | 13.4 | 14 |
| BW | 5.6 | 5.5 | 6.7 | 8.6 | 8.4 |
| ED | 1.4 | 1.4 | 1.5 | 2 | 2.2 |
| IP | 4.1 | 4.1 | 4.3 | 5.2 | 5 |
| IND | 2.2 | 2.2 | 2.3 | 2.8 | 2.4 |
| NPD | 1.9 | 2.4 | 2.3 | 2.6 | 2.8 |
| RND | 1.9 | 1.8 | 1.5 | 1.9 | 1.6 |
| SP | 3.7 | 3.5 | 3.8 | 4.2 | 4 |
| ODW | 2.3 | 2.6 | 2.7 | 3.6 | 3 |
| NK | 38 | 37 | 35 | 42 | - |
| NP | 73 | 98 | 106 | 96 | 10.3 |
| SS | 7.5 | 7.5 | 8.7 | 8.6 | 9.2 |
| TL | 30.1 | 35.2 | 39.3 | 42.8 | 44.3 |
| TAL | 18.5 | 23.2 | 26.1 | 29.1 | 30.8 |
| TMH | 3.4 | 3.2 | 3.4 | 3.8 | 3.6 |
| TMW | 2.4 | 2.6 | 2.4 | 3.5 | 3 |
| UF | 1.6 | 1.4 | 1.5 | 2.3 | 1.5 |
| LF | 1.3 | 1.1 | 1.5 | 1.7 | 0.9 |
| KRF | 1:4+4/2+2:1 | 1:3+4/1+1:2 | 1:4+4/1+1:2 | 1:4+4/3 | - |
| LTRF | 5(2-5)/3(1-2) | 5(2-5)/3(1) | 5(2-5)/3(1) | 5(2-5)/3 | - |

the tip of snout than to the eye.

*Juveniles (n = 4; SVL 24.8-31.5 mm)*: The following description is based on specimen ZFMK 89788 (SVL 27.9 mm).

The juveniles in preservative differ from the available froglet series by having a more violet dorsum. The ventral side is white to fawn. Fore limbs and hind limbs are dorsally covered with violet pigments, with darker brown pigmentation on hands and feet, except for finger I. Venter is fawn. Colouration of dorsum fades to colouration of belly. Except for the region of the cloaca and the outer arm, starting from elbow until the tip of finger IV, and except for the region of the outer leg, starting from tibio-tarsal joint until the tip of toe V, where a white line followed by a brown line is separating the violet region from the ventral colouration.

In life, dorsum is light green. The green region fades to the light yellow venter with a narrow white stripe on the flank. Dorsal surface of fore limbs and hind limbs is light green with a lateral white stripe, more distinct on the hind limbs. Toes are dorsally grey to white with yellowish discs. A black spot is sometimes present on the throat (Fig. 3D).

Body is oval; head is large and long (head length is 0.32 and head width 0.41 of total length); snout is rounded, with distinct canthus rostralis; eyes are moderately large (eye diameter is 0.34 of head length); supratympanic fold is distinct; tympanum is very small (diameter of tympanum is 0.45 of diameter of eye); nostrils are equi -

TAB. 2: Measurements (in mm) of freshly metamorphosed froglets of *Rhacophorus maximus* from the Tay Yen Tu Nature Reserve, Bac Giang Province, North-Eastern Vietnam; for abbreviations see material and methods.

| | MHNG 2721.52 | ZFMK 89790 | IEBR A.0941 |
|---|---|---|---|
| stage | 45 | 46 | 46 |
| SVL | 17.5 | 16.8 | 19.0 |
| HW | 6.6 | 6.7 | 7.4 |
| HL | 4.4 | 4.8 | 5.4 |
| EN | 1.4 | 1.5 | 1.6 |
| NS | 1.2 | 1.7 | 1.8 |
| ED | 2.7 | 2.8 | 3.1 |
| TD | - | - | - |
| FLL | 11.8 | 11.7 | 11.9 |
| HLL | 22.6 | 20.3 | 22.9 |
| FL | 6.7 | 6.2 | 7.4 |
| IMT | 0.9 | 0.8 | 1.1 |

distant from snout and eyes; vomerine teeth are distinct; vocal sac is not visible.

Fore limbs are relatively short (fore limb length is 0.55 of total length); the relative length of fingers is the same as described above for froglets.

Hind limbs are relatively long (length of hind limb is 1.33 of total length); the relative length of toes is the same as described for froglets; feet are fully webbed.

Specimens MHNG 2721.51 (except for the lacking tympanum and nostrils being closer to tip of snout than to eyes), VNMN 1212 (except for nostrils being closer to eyes than to tip of snout), and ZFMK 89787 (SVL 24.8-31.5 mm) largely correspond to this description (see Table 3 for measurements), as do other juveniles that were only photographed at the Amphibian Station in Hanoi.

*Subadults (n = 4; SVL 38.4-50.8 mm)*: The following description is based on the wild-caught specimen IEBR A.0940 (SVL 50.8 mm), which proved to be genetically completely identical to the syntopic adult specimen IEBR 3653.

In preservative, the body is blue to violet with single white spots on the back. The light colour in the ventral region is clearly intercepted from the blue pattern on the back by a white stripe on the lateral side, followed by an irregular brown line, fading to the fawn belly. The white lateral stripe starts from behind the mouth to the groin. The upper jaw is lacking pigmentation at the mouth opening. Dorsal surface of the fore limbs, fingers III and IV are blue to violet, separated from the light colour on ventral side by a white stripe. Webbing, discs and fingers II-III are dorsally slightly brown. The ventral side of fore limbs is white to fawn, the same colour on dorsal fingers I and II. The dorsal surface of hind limbs, toes IV-V, and webbing between toes IV and V is blue to violet. The region around cloaca is brown pigmented with a short white stripe separating the blue from the brown colouration. Femur is fawn to yellow below, with brown pigmentation fading from the blue to the fawn region, lacking a white stripe. Femur has brown spots in the postlateral region. Tibia is fawn to yellow below. The knee region shows a white line anteriorly following a brown stripe separating the blue from the fawn region. Toes are fawn to yellow below. Webbing and discs have brown pigmen-

TAB. 3: Measurements (in mm) of juvenile *Rhacophorus maximus* from the Tay Yen Tu Nature Reserve, Bac Giang Province, North-Eastern Vietnam; for abbreviations see material and methods.

| | VNMN 1212 | MHNG 2721.51 | ZFMK 89787 | ZFMK 89788 |
|---|---|---|---|---|
| SVL | 27.5 | 24.8 | 31.5 | 27.9 |
| HW | 11.4 | 10.3 | 12.9 | 11.4 |
| HL | 9.2 | 8.3 | 9.7 | 9.0 |
| EN | 2.4 | 2.3 | 2.8 | 2.4 |
| NS | 2.6 | 2.1 | 2.9 | 2.5 |
| ED | 3.6 | 3.6 | 3.7 | 3.1 |
| TD | 1.9 | - | 1.4 | 1.4 |
| FLL | 16.0 | 12.7 | 16.3 | 15.2 |
| HLL | 35.5 | 31.7 | 43.9 | 37.0 |
| FL | 10.6 | 9.0 | 12.3 | 10.8 |
| IMT | 1.1 | 1.2 | 1.1 | 0.9 |

TAB. 4: Measurements (in mm) of subadult *Rhacophorus maximus* from the Tay Yen Tu Nature Reserve, Bac Giang Province, North-Eastern Vietnam; for abbreviations see material and methods.

| | VNMN 1211 | IEBR A.0940 | MHNG 2721.50 | ZFMK 89786 |
|---|---|---|---|---|
| SVL | 41.0 | 50.8 | 49.1 | 38.4 |
| HW | 15.9 | 19.6 | 19.1 | 14.4 |
| HL | 14.0 | 16.7 | 17.0 | 12.0 |
| EN | 3.7 | 4.3 | 3.9 | 2.9 |
| NS | 3.5 | 4.5 | 4.5 | 3.0 |
| ED | 5.0 | 5.6 | 6.0 | 5.1 |
| TD | 2.8 | 3.1 | 2.7 | 1.4 |
| FLL | 23.4 | 26.6 | 25.7 | 19.3 |
| HLL | 57.7 | 72.5 | 68.6 | 48.0 |
| FL | 15.8 | 21.3 | 20.1 | 13.5 |
| IMT | 1.5 | 2.2 | 1.5 | 1.5 |

tation dorsally. A white stripe followed by a brown stripe separates the blue from the fawn region posteriorly to tibio-tarsal joint, running down until the tip of toe V.

Dorsum in life is green with single light green spots on the back; venter is yellow to fawn. The light colour in ventral region is intercepted from the green colour on back by a white stripe on lateral side, followed by a brown stripe fading to the yellow belly. Dorsal surface of fore limbs, fingers III and IV are green. Lower surface of fore limbs is yellow with red fingers. The green colouration on the dorsal fore limbs is clearly separated from the white colour in ventral region by a white stripe. Fingers I and II are yellow on both upper and lower sides, including the discs. Webbing of fingers is completely red. Dorsal surface of hind limbs and fingers IV-V is green. The cloacal region is red to violet with a short white stripe separating the green from the red colouration. The inner edge and underside of femur are red. The red colouration of legs fades to the yellow to fawn belly. Tibia is red below. The anterior knee region shows a white stripe following a violet stripe separating the green from the red colou-

ration. Toes are red below, except for toe V being violet. Toes I and II as well as webbing between toes are red, except for the webbing between toes IV and V, being green in part. Toe III is red above. From tibio-tarsal joint downwards a white stripe followed by a narrow violet stripe is separating the green upper from the red lower (Fig. 6A, B).

Body is stocky, width at chest is double the width at hip. Head is strikingly large (head length is 0.33 and head width 0.39 of total length). Snout is rounded and slightly surpasses lower jaw. Canthus rostralis is distinct and angular. Nostrils are laterally positioned, roundish to triangular, and slightly closer to the eyes than to the tip of snout. Eyes are relatively large (eye diameter is 0.33 of head length). Tympanum is small (diameter of tympanum is 0.56 of eye diameter) and partially covered by a distinct supratympanic fold. Vomerine teeth are distinct. Tongue is deeply notched, vocal sac is indistinct. The dorsal skin is smooth. Belly and femur are covered with coarse granules below.

Fore limbs are rather small (length of fore limb is 0.53 of total length) with a relatively finger length as described for froglets and juveniles. Adhesive discs are enlarged and round to triangular, smallest on finger I. Fingers are nearly fully webbed. Subarticular tubercles are well developed and lumped. Palmar tubercle is well developed, whereas thenar tubercle is absent. Metacarpal tubercles are only indistinctly discernible.

Hind limbs are long and relatively slender (length of hind limb is 1.43 of total length). The relative length of toes is the same as described for froglets and juveniles. Adhesive discs are enlarged and round to semicircular, smallest on finger I. Toes are fully webbed. Subarticular tubercles are well developed and lumped. The inner metatarsal tubercle is rather flat and oval. The outer metatarsal tubercle is lacking.

The wild caught specimens MHNG 2721.50, VNMN 1211 and ZFMK 89786 from Tay Yen Tu with SVL 38.4-49.1 mm largely correspond to the above description, except for white spots on back and brown spots in the groin region (see Table 4 for measurements). However, subadult *R. maximus* (n = 7; SVL 37.8-61.0 mm) with the origin Tay Yen Tu bred in the Amphibian Station at Hanoi (and meanwhile kept in the amphibian unit of the Cologne Zoo) differ from the above description by lacking the distinct red webbing and the distinct red venter of hind limbs. In one subadult of *R. maximus* (SVL 53.8 mm) kept at the Cologne Zoo, we also observed that body portions such as the posterior and inner flanks, temporarily covered by the hind limbs, were slightly lighter (light green to yellow) than surrounding, not covered dorsal and lateral skin (Fig.6D).

## DISCUSSION

The genus *Rhacophorus* Kuhl & Van Hasselt, 1822 contains approximately 74 species (Li *et al.*, 2008), and is widely distributed across India, China, Japan, mainland South-East Asia, the Greater Sunda Island and the Philippines (Frost, 2009). In general, tadpole descriptions are only known for 17 species of about 74 reported *Rhacophorus* representatives (Flower, 1896; van Kampen, 1907; Pope, 1931; Bourret, 1942; Alcala & Brown, 1956; Inger, 1966; Iwasawa & Kawasaki, 1979; Inger, 1985; Inger & Tan, 1990; Hosoi *et al.*, 1995; Stuart *et al.*, 2006; Gillespie, 2007). Of the 18 *Rhacophorus*

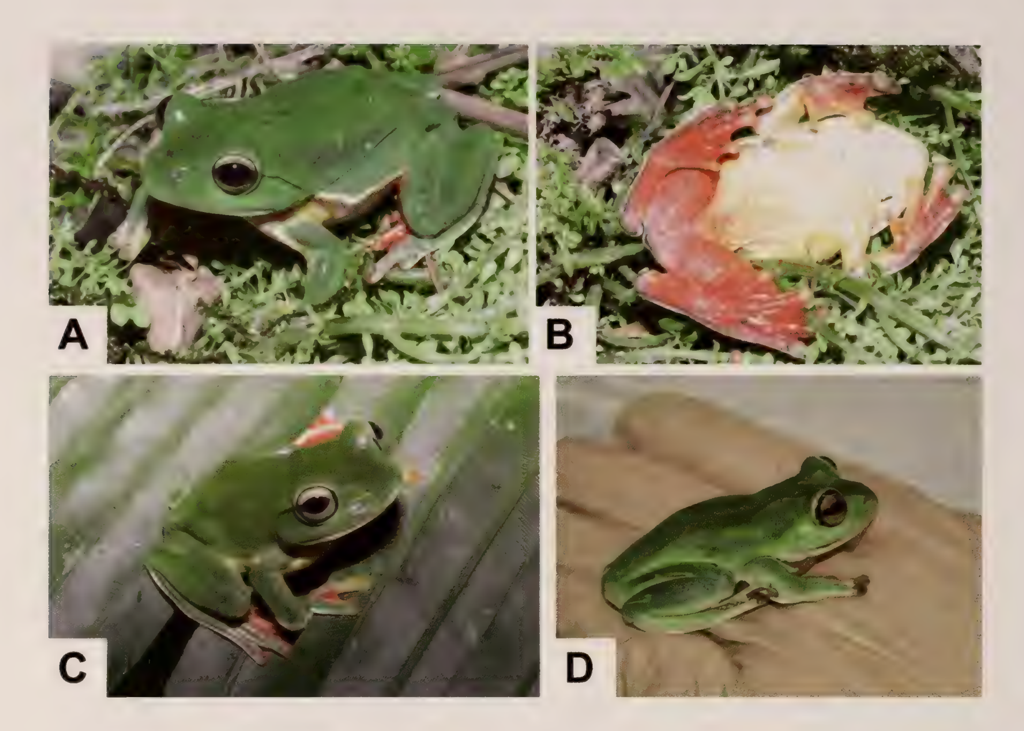


FIG. 6

Subadult *Rhacophorus maximus* (IEBR A.0940) from the Tay Yen Tu Nature Reserve, Bac Giang Province, north-eastern Vietnam, in life with distinct red webbing: (A) from above, (B) from below. Photographs by T. Ziegler. Subadult *R. maximus* in life: (C) in the habitat at Tay Yen Tu, and (D) in the terrarium at the Cologne Zoo. Photographs by T. Ziegler (C) and by D. Karbe (D).

species described from or recorded so far for Vietnam (Frost, 2009), only four larval descriptions are currently available, and among those only one tadpole description exists for Vietnamese *Rhacophorus* (see Table 5). However, tadpole descriptions are required because they facilitate identifications of early developmental stages of anurans and thus help to better understand their ecological requirements, which are important prerequisites for conservation measures.

Our tadpole description of *Rhacophorus maximus* from Vietnam largely agreed with larval descriptions available for other species of the genus in their main characteristics (Bourret, 1942; Inger, 1966): e.g., snout slightly rounded, eyes positioned laterally or dorsally; spiracle on left side; vent on right side (which does not reach the edge of the ventral fin); dorsal tail fin does not reach beyond base of tail. *Rhacophorus* larvae generally show a rather uniform morphology (Inger, 1966; 1985; Chou & Lin, 1997; Grosjean, 2004).

However, some species of *Rhacophorus* possess an uninterrupted row of marginal papillae on the lower labium, whereas others show a short medial gap (Hendrix *et al.*, 2007). With respect to the oral disk of the five *R. maximus* tadpoles studied by us, a medial gap in the lower lip is discernible. However, according to the tadpole

TAB. 5: List of Vietnamese *Rhacophorus* representatives (according to Frost 2009) including state of knowledge regarding morphological larval descriptions. * = Inger's (1985) larval description was based on *R. bimaculatus*.

| *Rhacophorus* | larval morphology known (based on non-Vietnamese larvae) | larval morphology known (based on Vietnamese larvae) |
|---|---|---|
| *annamensis* | | Hendrix *et al.* (2007) |
| *appendiculatus* | Inger (1966): Borneo | |
| *bipunctatus* | | |
| *calcaneus* | | |
| *chuyangsinensis* | | |
| *dennysi* | Pope (1931), Bourret (1942): China | |
| *dorsoviridis* | | |
| *duboisi* | | |
| *dugritei* | | Wildenhues *et al.* (in prep.) |
| *exechopygus* | | in preparation |
| *feae* | | Wildenhues *et al.* (in prep.) |
| *hoanglienensis* | | |
| *hungfuensis* | | |
| *kio* | | Wildenhues *et al.* (in prep.) |
| *marmoridorsum* | | |
| *maximus* | | Wildenhues *et al.* (this paper) |
| *orlovi* | | in preparation |
| *rhodopus* | Inger (1985): Borneo* | Wildenhues *et al.* (in prep.) |

drawings of Anders & Rai (2002) *R. maximus* larvae from Nepal obviously have no medial gap in the lower lip. In addition, the keratodont formula of larvae from Nepal differs not only from that of tadpoles from Vietnam, but also does not agree with the general keratodont formula for the genus *Rhacophorus* given by Bourret (1942), i.e., 2:1+1/3 in *R. maximus* larvae from Nepal versus 4-7/3-4. Although we observed a slight variation within the keratodont formula of tadpoles of *R. maximus* from Northern Vietnam, differences were not such distinct as it is obvious from the illustrations of larvae from Nepal provided by Anders & Rai (2002). Maybe tadpoles of *R. maximus*, which were illustrated in Anders & Rai (2002) were in early developmental stages. This could explain the aforementioned differences, because only the number and arrangement of labial tooth rows subsequent to Gosner stages 25-26 are stable enough to be species-specific (Altig & McDiarmid, 1999). Earlier stages of tadpoles can be compared only with specimens in the same stage of development (Gawor *et al.*, 2009).

Moreover, we could show for the first time that subadult *Rhacophorus maximus* have strong red colouration on hands, feet and lower, inner and outer legs. This obvious colour pattern change within individual development first led us to the assumption of a new species discovery, but was discarded regarding the results of our genetic comparisons. The assumption that the colour pattern change in *R. maximus* is age dependent is underlined by the fact that red webbings only occur in wild-caught subadults from Vietnam but are lacking in syntopic adults. However, the lack of distinct red limb colouration in specimens from Vietnam kept at the Cologne Zoo, which at best show a slight, pale red pattern, shows at least that it may be subject to husbandry and/or climatic conditions. This, as well as the colour pattern change in the green ground colouration as described above certainly deserves further research. Among the

tree frogs occurring in the Indochinese region of South-East Asia, the following nominal species show red web on feet and green dorsal ground colour (Bordoloi *et al.*, 2007): *R. bipunctatus* Ahl, 1972; *R. htunwini* Wilkinson, Thin, Lwin & Shein, 2005; *R. kio* Ohler & Delmore, 2006; *R. malabaricus* Jerdon, 1870; *R. reinwardtii* Schlegel, 1840; *R. rhodopus* Liu & Hu, 1960; *R. suffry* Bordoloi, Bortamuli & Ohler, 2007, and *R. yaoshanensis* Li & Hu, 1962. In view of our results, the question must be raised whether the red webbing between toes and fingers of some of the latter species is just an age dependent colour pattern change, or whether red webbing may occur in certain developmental stages of additional *Rhacophorus* species, but was not yet recorded so far.

With respect to *Rhacophorus maximus*, further questions remain to be clarified: are the differences between Western and Eastern tadpoles due to developmental stages, as was discussed above, or does this already indicate possibly differing taxa? DNA fragments of *R. maximus* from Vietnam (IEBR 3653) compared to those of *R. maximus* from Simao, Yunnan, China (GenBank accession number: EF564548) were not completely identical (ca. 0.6% difference). Thus, a more in-depth genetic comparison of the more distant Eastern populations with Western populations would be worthwhile. Unfortunately, comparative material from Nepal could not be analysed so far. This is also underlined by the recently described *R. suffry* from India, which seems very similar to the red-webbed developmental stage of *R. maximus* from Vietnam as described in this paper.

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## REFERENCES

ALCALA, A. C. & BROWN, W. C. 1956. Early life history of two Philippine frogs with notes on deposition of eggs. *Herpetologica* 12: 241-246.

ALTIG, R. & MC DIARMID, R.W. 1999. Bodyplan: Development and morphology (pp. 24-51). In: ALTIG, R. & MC DIARMID, R.W. (eds) Tadpoles: The biology of anuran larvae. *University of Chicago Press, Chicago & London.*

ANDERS, C. & RAI, K. R. 2002. *Rhacophorus maximus* GÜNTHER, 1859 „1858" (pp. 337-340). In: SCHLEICH, H. H. & KÄSTLE, W. (eds) Amphibians and Reptiles of Nepal. Biology, Systematics, Field Guide, *A. R. G. Ganter Verlag K. G, Ruggell.*

BIRDLIFE INTERNATIONAL, 2004. Sourcebook of existing and proposed protected areas in Vietnam. Second Editon. Updated 04/23/04 (see http://birdlifeindochina.org/vi/publication).

BORDOLOI, S., BORTAMULI, T. & OHLER, A. 2007. Systematics of the genus *Rhacophorus* (Amphibia, Anura) identity of red-webbed forms and description of a new species from Assam. *Zootaxa* 1653: 1-20.

BOULENGER, G. A. 1890. The fauna of British India including Ceylon and Burma, Reptilia and Batrachia. *London*, 541 pp.

BOURRET, R. 1942. Les batraciens de l'Indochine. *Institut Océanographique de l'Indochine, Hanoi*, 408 pp.

BWONG, B. A., CHIRA, R., SCHICK, S., VEITH, M. & LÖTTERS, S. 2009. Diversity of Ridged Frogs (Ptychadenidae: *Ptychadena*) in the Easternmost remnant of the Guinea-Congolean rain forest: an analysis using morphology, bioacoustics and molecular genetics. *Salamandra* 45 (3): 129-146.

CHOU, W. H. & LIN, J. Y. 1997. Tadpoles of Taiwan. *National Museum of Natural Science Special Publication* 7: 1-98.

DUBOIS, A. 1995. Keratodont formulae in anuran tadpoles: proposal for a standardization. *Journal of Zoological Systematics and Evolutionary Research* 33: 1-15.

FEI, L. 1999. Atlas of Amphibians of China. *Edited by Committee, C. W. P. Zhengthou, Henan Publishing House of Science and Technology, Chengdu*, 432 pp.

FLOWER, S. S. 1896. Notes on a collection of reptiles and batrachians made in the Malay Peninsula. *Proceedings of the Zoological Society London* 1896: 856-916.

FROST, D. 2009. Amphibian Species of the World: an Online Reference. Version 5.3 (12, February, 2009). Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/ *American Museum of Natural History, New York, USA.*

GAWOR, A., HENDRIX, R., VENCES, M., BÖHME, W. & ZIEGLER, T. 2009. Larval morphology in four species of *Hylarana* from Vietnam and Thailand with comments on the taxonomy of *H. nigrovittata* sensu latu (Anura: Ranidae). *Zootaxa* 2051: 1-25.

GILLESPIE, G. R., ANSTIS, M., HOWARD, S. D. & LOCKIE, D. 2007. Description of the tadpole of the rhacophorid frog *Rhacophorus georgii* Roux (Rhacophoridae) from Sulawesi, Indonesia. *Journal of Herpetology* 41: 150-153.

GLAW, F. & VENCES, M. 1994. A field guide to the amphibians and reptiles of Madagascar, 2nd edition. *Vences & Glaw Verlag, Köln*, 480 pp.

GROSJEAN, S. 2004. Apport des caractè res larvaires à la phylogénie des Amphibiens Anoures. Cas de deux familles: les megophryidae et les Ranidae. *Unpublished thesis, Muséum National d'Histoire Naturelle, Paris* i-iv + 1-177 + [i-xxiv] + 1-261 + [i-cx] + 101 pl.

GROSJEAN, S. 2005. The choice of external morphological characters and developmental stages for tadpole-based anuran taxonomy: a case study in Rana *(Sylvirana) nigrovittata* (Blyth, 1855) (Amphibia, Anura, Ranidae). *Contributions to Zoology* 74: 1-22.

GOSNER, K. L. 1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* 16: 183-190.

GÜNTHER, A. 1858. Neue Batrachier in der Sammlung des Britishen Museums A*rchiv für Naturgeschichte* 24: 319-328.

HALL, T.A. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95-98.

HENDRIX, R., GROSJEAN, S., LE, Q. K., VENCES, M., VU, T. N., & ZIEGLER, T. 2007. Molecular identification and description of the tadpole of the Annam Flying frog, *Rhacophorus annamensis* SMITH, 1924 (Anura : Rhacophoridae). *Salamandra* 43: 11-19.

HOSOI, M., NIIDA, S., YOSHIKO, Y., SUEMUNE, S. & MAEDA, N. 1995. Scanning electron microscopy of horny teeth in the anuran tadpole Rhacophoridae, *Rhacophorus arboreus and Rhacophorus schlegelii*. *Journal of Electron Microscopy* 44: 351-357.

INGER, R. F. 1966. The systematics and zoogeography of the Amphibian of Borneo. *Fieldiana: Zoology* 52: 1-402.

INGER, R. F. 1985. Tadpoles of the forested regions of Borneo. *Fieldiana: Zoology* (new series) 26: 1-89.

INGER, R. F. & TAN, F. L. 1990. Recently discovered and newly assigned frog larvae (Ranidae and Rhacophoridae) from Borneo. *Raffles Bulletin of Zoology* 38: 3-9.

IWASAKA, H. & KAWASAKI, N. 1979. Normal stages of development of the Japanese Green Frog *Rhacophorus arboreus* (Okada et Kawano). *Japanese Journal of Herpetology* 8: 22-35.

KHONGWIR, S., IANGRAI, A. & HOOROO, N. K. 2003. Development of mouth parts and food choice in the tadpoles of *Rhacophorus maximus*. *Uttar Pradesh Journal of Zoology* 23: 101-04.

LI, J.-T., CHE, J., BAIN, R. H., ZHAO, E.-M. & ZHANG, Y.-P. 2008. Molecular phylogeny of Rhacophoridae (Anura): A framework of taxonomic reassignment of species within the genera *Aquixalus, Chiromantis, Rhacophorus* and *Philautus*. *Molecular Phylogenetics and Evolution* 48: 302-312.

MANTHEY, U. & GROSSMANN, W. 1997. Amphibien und Reptilien Südostasiens. *Natur- und Tier Verlag, Münster*, pp. 512.

NGUYEN, T. T., TRAN, T. T., NGUYEN, Q. T. & PHAM, T. 2008. *Rhacophorus maximus* (Nepal Flying Frog). *Herpetological Review* 39: 364.

NGUYEN, V. S., HO, T. C. & NGUYEN, Q. T. 2009. Herpetofauna of Vietnam. *Edition Chimaira, Franfurt Contribution to Natural History, volume 33, Frankfurt am Main*, 768 pp.

ORTON, G. L. 1953. The systematics of vertebrate larvae. *Systematic Zoology* 2: 63-75.

PALUMBI, S. R., MARTIN, A., ROMANO, S., MCMILLAN, W. O., STICE, L. & GRABOWSKI, G. 1991. The simple fool's guide to PCR. *Department of Zoology and Kewalo Marine Laboratory, Hawaii*, 47 pp.

POPE, C. H. 1931. Notes on Amphibians from Fukien, Hainan, and other parts of China. *Bulletin of the American Museum of Natural History* 59: 597-611.

SCHMITZ, A., INEICH, I. & CHIRIO, L. 2005. Molecular review of the genus *Panaspis* sensu lato in Cameroon, with special reference to the status of the proposed subgenera. *Zootaxa* 863: 1-28.

SINHA, B., CHAKRAVORTY, P., BORAH, M. M. & BORDOLOI, S. 2001. Qualitative analysis of food spectrum of five species of anuran tadpoles from Arunachal Prasesh, India. *Zoo's Print Journal* 16: 514-515.

STUART, B. L., CHUAYNKERN, Y., CHAN-ARD, T. & INGER, R. F. 2006. Three new species of frogs and a new tadpole of Eastern Thailand. *Fieldiana: Zoology* 111: 1-19.

VAN KAMPEN, P. N. 1907. Amphibien des Indischen Archipels. *Zoologische Ergebnisse, Reise Niederländisches Ost-Indien* 4: 383-416.

VENCES, M., THOMAS, M., VAN DER MEIJDEN, A., CHIARI, A. & VIEITES, D. R. 2005. Comparative performance of the 16S rRNA gene in DNA barcoding of amphibians. *Frontiers in Zoology*, 2: 5.

YANG, D. T., LI, S., LIU, W. & LÜ, S. 1991. The Amphibia Fauna of Yunnan. *China Forestry Publishing House, Beijing*, 259 pp.

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# The Gelechiidae (Lepidoptera) of the Galapagos Islands, Ecuador, a taxonomic revision

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**The Gelechiidae (Lepidoptera) of the Galapagos Islands, Ecuador, a taxonomic revision.** - The Gelechiidae of the Galapagos Islands are revised. Twenty-two species are recognized to be established on the archipelago, including eight described as new: *Ephysteris sporobolella* Landry (bred from *Sporobolus virginicus* (L.) Kunth (Poaceae)), *E. scimitarella* Landry, *Scrobipalpula inornata* Landry, *S. equatoriella* Landry, *S. caustonae* Landry, *Stegasta francisci* Landry, *Symmetrischema escondidella* Landry, and *Untomia lunatella* Landry. *Agnippe omphalopa* (Meyrick, 1917), comb. n., *Anacampsis primigenia* Meyrick, 1918, *Aristotelia sarcodes* Walsingham, 1910, *Compsolechia salebrosa* Meyrick, 1918, *Dichomeris acuminatus* (Staudinger, 1876), *Ephysteris subdiminutella* (Stainton, 1867), *Mesophleps adustipennis* (Walsingham, 1897) comb. n., *Phthorimaea perfidiosa* Meyrick, 1917, *Scrobipalpula densata* (Meyrick, 1917), and *Stegasta zygotoma* Meyrick, 1917 are reported from the archipelago for the first time. Four additional species had been reported from the archipelago before. A lectotype is designated for *Echinoglossa trinota* Clarke, 1965 from Masatierra, Juan Fernandez Islands. New host plant records are provided for *A. omphalopa*, *A. primigenia*, *C. salebrosa*, *M. adustipennis*, and *P. absoluta*.

**Keywords:** Microlepidoptera - Gelechioidea - Gelechiinae - Anomologini - Anacampsini - Gelechiini - Gnorimoschemini - Litini - Dichomeridinae - Pexicopiinae - host plants - Neotropical Region.

## INTRODUCTION

The Gelechiidae are a very large family of microlepidoptera within the hyper diverse Gelechioidea. More than 4,530 species have been described (Hodges, 1998), and whilst 855 have been reported from the Neotropical Region (Heppner, 1991), their diversity in this region far exceeds this number.

Gelechiidae were first reported from the Galapagos Islands by Schaus (1923). However, both of the species mentioned by Schaus are believed to represent erroneous records as mentioned by Schmitz & Landry (2007). The unique specimen of *Aristotelia howardi* Walsingham, 1909 recorded by Schaus from South Seymour is believed to be

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the species described three years later by Meyrick as *Aristotelia naxia* Meyrick, even though *A. howardi*, described from Mexico, is paler and with different forewing markings, especially on apical third (see http://www.sil.si.edu/DigitalCollections/bca/navigation/bca_15_04_00/bca_15_04_00plates.cfm). No other species of Gelechiidae are more similar to *A. howardi* than *A. naxia* in the Galapagos. *Gelechia bosqueella* Chambers, 1875, (now in *Stegasta* Meyrick) was reported by Schaus from one specimen collected at Conway Bay, Indefatigable (now Santa Cruz). This record is believed to represent *Stegasta zygotoma* Meyrick, 1917.

Following Schaus, Meyrick (1926) recorded three species of Gelechiidae from the Galapagos, all of which he described as new. Two of these were transferred to the Autostichidae genus *Galagete* Landry (Landry, 2002) while the third is *Aristotelia naxia*. The five taxa mentioned by Schaus and Meyrick were listed by Linsley & Usinger (1966) and *A. naxia* was mentioned again by Linsley (1977).

*Stoeberhinus testaceus* Butler, 1881, was recorded as a Gelechiidae 'supposedly also in the Galapagos' by Zimmerman (1978: 1806), but the origin of this supposition was not found. Perhaps it comes from Meyrick (1927) who recorded it from several Pacific islands and added 'apparently throughout the Pacific Islands'. The species was then positively recorded from the archipelago by Clarke (1986: 171). However, it was not mentioned by Schaus (1923) and Meyrick (1926), nor was it listed by Linsley & Usinger (1966) and Linsley (1977), nor is it represented by Galapagos specimens in the BMNH. We conclude that it is not present yet in the Galapagos Islands. This taxon was also moved to the Autostichidae (see Hodges, 1998).

The next and last previous records of Gelechiidae on the Galapagos are those of *Sitotroga cerealella* (Olivier, 1789) and *Phthorimaea absoluta* Meyrick, 1917, (as *Tuta absoluta*) in Causton *et al.* (2006), and the description of *Chionodes stefaniae* by Schmitz & Landry (2007). Thus, only four valid species of Gelechiidae have been reported so far from Galapagos. Below we report another 18 species, 8 of which are described as new. These 22 Galapagos species of Gelechiidae are listed in a check-list following the conclusion. Two additional species (Figs 39, 40, 101, 102) of Gnorimoschemini, known from only three female specimens altogether (MHNG), are not taxonomically treated here because of the lack of material.

## MATERIAL AND METHODS

The manner of giving the label data of the holotypes and paratypes is presented in Landry (2006) as are the methods used for specimen collecting. Most of the material forming the basis of this study was collected by ourselves at light, but we also reared some of the species. This material is mostly deposited in the Charles Darwin Research Station, Santa Cruz Islands, Galapagos, Ecuador (CDRS), Canadian National Collection of Insects, Ottawa, Canada (CNC), and Muséum d'histoire naturelle, Geneva, Switzerland (MHNG), which also includes specimens collected between 2004 and 2006 by P. Schmitz. We also studied older material from the Natural History Museum, London, UK (BMNH), the California Academy of Sciences, San Francisco (CAS), and the National Museum of Natural History, Washington, DC, USA (USNM). The host plant nomenclature follows Lawesson *et al.* (1987) and the information on island sizes comes from Peck (2001).

The previously described species are given additional descriptions of the sex and parts that were not treated in the original descriptions or elsewhere. The material examined for these species is given in alphabetical order of islands and within each island in increasing order of elevation, but the collector names and collecting dates are omitted.

The terminology of the genitalia generally follows Kristensen (2003), but the names of two of the male genital structures in Gnorimoschemini (parabasal process, sacculus processes) are from Povolný (e.g. 1999, 2002). The male genital illustrations for each species are at the same scale when the phallus is illustrated separately from the rest of the genitalia. However, the male and female genitalia of different species on each plate are not to scale, as in the illustrations of the moths.

**Systematic check-list of Galapagos Gelechiidae**

Gelechiinae, Anomologini

- *Aristotelia naxia* Meyrick, 1926
- *Aristotelia sarcodes* Walsingham, 1910

Gelechiinae, Gelechiini

- *Chionodes stefaniae* Schmitz & Landry, 2007
- *Stegasta zygotoma* Meyrick, 1917
- *Stegasta francisci* Landry, sp. n.

Gelechiinae, Gnorimoschemini

- *Ephysteris scimitarella* Landry, sp. n.
- *Ephysteris sporobolella* Landry, sp. n.
- *Ephysteris subdiminutella* (Stainton, 1867)
- *Phthorimaea absoluta* Meyrick, 1917
- *Phthorimaea perfidiosa* Meyrick, 1917
- *Scrobipalpula densata* (Meyrick, 1917)
- *Scrobipalpula equatoriella* Landry, sp. n.
- *Scrobipalpula inornata* Landry, sp. n.
- *Symmetrischema caustonae* Landry, sp. n.
- *Symmetrischema escondidella* Landry, sp. n.

Gelechiinae, Litini

- *Agnippe omphalopa* (Meyrick, 1917), comb. n.

Gelechiinae, Anacampsini

- *Anacampsis primigenia* Meyrick, 1918
- *Compsolechia salebrosa* Meyrick, 1918
- *Mesophleps adustipennis* (Walsingham, 1897), comb. n.
- *Untomia lunatella* Landry, sp. n.

Pexicopiinae

- *Sitotroga cerealella* (Olivier, 1789)

Dichomeridinae

- *Dichomeris acuminatus* (Staudinger, 1876)

## SYSTEMATIC PART

### Gelechiinae

### Anomologini

***Aristotelia*** Hübner, [1825]

A large and widespread genus containing 35 species in the Nearctic region (Lee et al., 2009), 42 in the Neotropics (Becker, 1984), and 14 in Europe (Karsholt & Riedl, 1996), for example. Meyrick (1925) provided a World list of 238 species, but his concept of the genus was much broader than today's. Beccaloni *et al.* (2003) list 149 names, including synonyms. In the Galapagos two species occur, but their host plants are unknown. Other species of *Aristotelia* have been reared from a wide range of host plant families such as Asteraceae, Euphorbiaceae, Fabaceae, Polygonaceae, Rosaceae, Solanaceae, etc. (see Robinson *et al.*, 2007).

***Aristotelia naxia*** Meyrick, 1926 Figs 1, 41, 42, 80–82

*Aristotelia naxia* Meyrick, 1926: 277. – Linsley & Usinger, 1966: 164. – Linsley, 1977: 37. – Becker, 1984: 45.

Material examined: 28 ♂, 35 ♀. Male holotype, described from Charles [Floreana] Island, and collected in July [labels and dissection number not recorded] (BMNH). – *Espanola*: bahia Manzanillo. – *Fernandina*: SW side, crater rim, 1341 m elev., S 00° 21.910' W 091° 34.034'. – *Floreana*: Las Cuevas; Punta Cormoran; close to Loberia, 6 m elev. – *Genovesa*: bahia Darwin. – *Isabela, Alcedo*: lado NE, plaja; NE slope, near shore, 9 m elev., S 00° 23.619' W 90° 59.715'; lado NE, low arid zone; lado Este, 700 m elev. – *Isabela, Darwin*: Tagus Cove; 200 m elev.; [W slope] 300 m elev.; [W slope] 630 m elev. – *Isabela, Sierra Negra*: 2 km W Puerto Villamil; 8.5 km N Puerto Villamil. – *Marchena*: no specified locality. – *Pinta*: plaja Ibbetson, N 00° 32.819' W 90° 44.229'; ±15 m elev.; ±50 m elev.; ±200 m elev.; ±400 m elev. – *Pinzon*: playa Escondida, 00° 35.928' W 90° 39.291'. – *Rabida*: tourist trail. – *San Cristobal*: Puerto Baquerizo; near Loberia, 14 m elev., S 00° 55.149' W 89° 36.897'; 2 km SW Puerto Baquerizo; 4 km SE Puerto Baquerizo; base of Cerro Pelado; 1 km S El Progreso. – *Santa Cruz*: bahia Conway; Charles Darwin Research Station; 2 km W Bella Vista; transition zone, house of L. Roque, 137 m elev., S 00° 42.595' W 90° 19.196'; transition zone, recently cut road, S 00° 42.528' W 90° 18.849'; finca Steve Devine; finca Vilema, 2 km W Bella Vista; Los Gemelos. – *Santiago*: Bahia Espumilla; La Bomba, 6 m elev., S 00° 11.151' W 90° 42.052'; N side, 147 m elev., S 00° 12.186' W 90° 42.888'; 200 m elev.; Cerro Inn; Aguacate, 520 m elev. – *Seymour Norte*: 13 m elev., S 00° 24.013' W 90° 17.422'; [no specified locality]. Deposited in BMNH, CDRS, CNC, and MHNG.

Diagnosis: Among the Gelechiidae of the Galapagos, the forewing pattern of *A. naxia* with dark brown markings over a grey background will separate it immediately from all other species. The subbasal outwardly oblique bar, the median, incomplete V, the often complete band at 2/3, and the costal preapical spot are diagnostic. The most similar gelechiid species in the Galapagos would be the smaller (max. 11 mm wingspan) *Stegasta zygotoma* Meyrick and *S. francisci* sp. n. (Figs 5, 6) which also have paler markings, especially in the form of a large triangle at the base of the inner margin, and a subapical costal spot. *Aristotelia naxia* is similar to *A. roseosuffusella* (Clemens, 1860), described from Pennsylvania, USA, but the forewing of the latter has a salmon anal triangle, a white streak below apex, and a triangular streak subapically on costa. *Aristotelia psoraleae* Braun, 1930, has forewing markings similar to those of *A. roseosuffusella*. *Aristotelia cynthia* Meyrick, 1917, has forewing markings similar to those of *A. naxia*, but the male genitalia have widely differently shaped valvae and

uncus (See Clarke, 1969a: 283). Lastly, *A. perfossa* Meyrick, 1917 also has forewing markings similar to those of *A. naxia*, although not as contrasted, but the phallus is more simple and the uncus and valvae are shorter and not as sharply pointed apically (See Clarke, 1969a: 299).

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=27): Head with ocelli. Scape without pecten. Forewing length: 4.3–5.5 mm. Without hair pencil from base of hindwing costa. Sternum VIII apically forming pair of broadly rounded lateral projections 1/3 longer than median shortest length of sternum.

Male genitalia (n=3) (Figs 41, 42). Uncus evenly narrowing to roughly pointed apex, slightly downcurved, sparsely setose dorsally, more densely setose and with longer setae at base of branches ventrally. Gnathos almost as long as uncus, median hook free from arms for half of gnathos' length, curved upward at right angle from 3/4. Tegumen rather long and narrow, dorsal connection about half as long as whole tegumen, basal half at right angle from apical half, margins (especially dorsal margin) strongly reinforced especially on basal half, apical half dorsally flat, apical 1/4 appearing to form separate sclerite dorsomedially with rather wide unsclerotized gap connected laterally with narrower incomplete 'sutures' (unsclerotized toward midline) reaching ventral margins of tegumen. Valva reduced to pair of long, narrow projections about 1/3 longer than tegumen, with apical 1/4 curved medially, apically narrowly acute, with short setae mostly along dorsal line from about 1/5 till subapex and at base. Vinculum trough-like, large, down curved, lateral margins narrowing till blunt, flat apex about 1/3 width of base, with short, sparse setation along dorsal margin laterally, slightly denser and longer along apical margin, the latter slightly notched medially. Membrane around phallus spinulose. Phallus broadly down curved, slightly shorter than tegumen, with large and round basal 2/5, narrowing to slightly widened middle, mediodorsally with narrow projection about as long as apical part, projecting antero-dextrally and apically rounded, apical 1/3 narrow, slightly narrowing, curving to left, and with lateral slit along left side, with apex pointing to left, rounded; vesica without cornuti.

*Female* (n=35) (Fig. 1): Antenna, colour, and forewing pattern as in male; with pencil of elongate scales at base of forewing Sc ventrally as in male; also with long hair-like scales on Anal vein of hindwing as in male; frenulum with three acanthae; forewing length: 4.3–5.75 mm. Sternum VII with margin broadly concave almost to middle of segment; tergum VII unmodified.

Female genitalia (n=4) (Figs 80–82). Papillae anales slightly elongate, sparsely setose but more densely so along ventral margin and apex, with longer setae dorsally at base. Posterior apophyses reaching middle of antrum when papillae not extended, slightly curved. Anterior apophyses short, about 1/3 length of posterior apophyses and thicker. Segment VIII broadly desclerotized dorsally, leaving only narrow (4/5 length) sclerotized band at base, ventrally with medioapical antrum a large quadrangular sclerotized tongue, curved ventrally and almost as large as rest of tergum VIII. Ductus bursae long and narrow, slightly enlarged and curved on proximal 1/10, before corpus bursae, spiny internally from about 1/5 to 9/10; ductus seminalis from short, narrow subbasal sac. Corpus bursae slightly elongate, scobinated on whole surface; large

signum on short, somewhat circular base protruding from wall of corpus with lateral extensions of short to long, thick spines.

BIOLOGY: Moths of *A. naxia* have been collected at light in all months of the year, except June and August, and mostly at low elevations, but also at higher localities, up to 700 m on Isabela.

DISTRIBUTION: A widespread and frequently observed endemic of the archipelago, *A. naxia* has been recorded from 13 of the 19 Galapagos islands of more than 1 $km^2$ and at all elevations.

REMARKS: The forewing pattern of *A. naxia* is similar to that of many other species of *Aristotelia* Hübner, but the male genitalia differ wildly from those of most other members of the genus, such as those of the type species, *Tinea decurtella* Hübner, from Europe. However, on the advice of K. Sattler (BMNH), who studied the illustrations of the genitalia that BL sent him, and those of the holotype, *A. naxia* should be left in *Aristotelia*. As K. Sattler wrote to BL: "The forewing pattern is typical of that genus and so is the bursa copulatrix with the internally spiny ductus and corpus bursae. The signum is also fairly typical and so is the pattern of the labial palpus."

Meyrick's (1926) description mentions "an expansible grey-whitish hairpencil from base of costa" on the hindwing. A tuft of elongate scales actually occurs ventrally on the forewing at base of Sc, but there is no hairpencil as found in the following species and arising from the base of the hindwing costa.

No significant variation was observed in the seven dissected genitalia examined.

***Aristotelia sarcodes*** Walsingham, 1910 Figs 2, 3, 43, 44, 83

*Aristotelia sarcodes* Walsingham, 1910: 26, pl. 1 fig. 23. – Meyrick, 1925: 47. – Becker, 1984: 45.

MATERIAL EXAMINED: 15 ♂, 5 ♀. Male holotype ♂ with the following labels: 'Tabernilla | CanalZone [sic] | Panama', 'Collected by | August Busck', '5842 | WLSM. 1908', 'ARISTOTELIA | SARCODES | Wlsm. Biol. C-Am. | no. .Pl. | (1909) | TYPE ♂ descr., figd. [undecipherable initial]', 'BL 1658 ♂', Loan from | USNMNH | 2048574': Specimen in poor condition, with most appendages broken except left hindleg and right labial palpus, and with right forewing detached, in a gelatine capsule (USNM). – Panama, CZ, Paraiso (USNM). – Ecuador, Galapagos, Islands: – *Floreana*: Las Cuevas. – *San Cristobal*: near Loberia, GPS: elev. 14 m, S 00° 55.149' W 89° 36.897'; antiguo botadero, ca. 4 km SE Puerto Baquerizo, GPS: elev. 169 m, S 00° 54.800' W 89° 34.574'. – *Santa Cruz*: Estacion Cientifica Charles Darwin. – *Seymour Norte*: No precise locality. Deposited in BMNH, CDRS, MHNG, USNM.

DIAGNOSIS: The salmon-pink colour of some of the forewing markings in this species is unique among Galapagos moths (Fig. 2). *Aristotelia roseosuffusella* (Clemens, 1860) and *A. rubidella* (Clemens, 1860) from eastern North America, *A. trossulella* Walsingham, 1897, from the Dominican Republic, as well as other species of *Aristotelia* have pink scales, but often of different hues and differently distributed. The other markings differ, notably the shiny silver bands and spots.

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=15) (Figs 2, 3). Head with ocelli. Scape without pecten. Forewing length: 4.0–4.3 mm (Holotype 4.2 mm); ventral surface (Fig. 3) with bunch of elongate, greyish-brown scales at base of Sc, most of surface beige to ochre-orange with large band of black-brown to grey-brown along margins. Hindwing with long, elaborate, ochre hairpencil at base of costa (Fig. 3),

reaching forewing tornus; Anal vein with long hair-like scales. Segment VIII about 1/3 longer than preceding segment, apical margin not modified.

Male genitalia (n=4) (Figs 43, 44). Uncus rather narrow, straight, arms of modest width with 4 setae (one long, three very short) at basoventral corner, more strongly sclerotized along lateral margins, subapically with or without (holotype) tiny, triangular dorsal projection slanted posteriorly, ventrally at 3/4 with low bump with few short setae. Gnathos with short lateral arms hinged to median hook of twice their length, hook narrow, only slightly upcurved, about half as long as uncus or slightly less. Dorsal part of tegumen slightly bulbous, connection about half as long as uncus, arms narrowing to 1/4 maximal dorsal width of tegumen. Membrane conspicuously scobinated laterally, more strongly so near connection of tegumen and valva. Valva somewhat spoon shaped in dorsal view with lateral margin straight and median margin with median concavity, dorsally spinulose at base and with few setae mostly short on apical half, in lateral view showing short, thumb-like, downward projection subapically. Vinculum posterior lobes somewhat laterally compressed, projecting medially and slightly downward, apicoventrally with narrow membranous connection, terminating with dorsal knob covered with short setose projections; saccus somewhat conical, with anterior end rounded and less strongly sclerotized; lateral arms slightly curved; posterior arms pointed and reaching posterior point of connection between posterior lobes of vinculum and valva. Phallus narrow, as long as vinculum + valva, slightly curved to left in dorsoventral view, slightly sinuous in lateral view, with rounded base, apically pointed; vesica spinulose, without cornuti.

*Female* (n=4): Antenna, colour, and forewing pattern as in male; with pencil of elongate scales at base of forewing Sc ventrally as in male; also with long hair-like scales on anal vein of hindwing as in male; without hairpencil at base of hindwing costa. Frenulum with three acanthae. Forewing length: 3.9–4.0 mm. Tergum VII not modified.

Female genitalia (n=3) (Fig. 83). Papillae anales moderately setose, with base more densely setose and basal margin with longest setae. Posterior apophyses narrow, straight except for shallow curve subbasally, rather short, almost reaching ostium when papillae not extended. Anterior apophyses short, about 1/3 length of posterior apophyses and slightly thicker. Segment VIII mostly membranous dorsally, laterally with few setae along apical margin; ventrally with pair of medially connected narrow plates recurved at basal margin to form two medially separate rounded plates projecting apically and laterally closed thus protecting medially located ostium. Ductus bursae long and narrow, with small narrow sclerite in membrane at connecting point of ductus seminalis at 1/5, proximal 2/3 (before corpus bursae) densely spiny internally, but spines blunt. Corpus bursae elongate, about half as long as ductus bursae, lightly scobinated; single signum situated posteriorly to middle of corpus bursae, lozenge shaped in frontal view, with perpendicular slit in middle forming hole in membrane, in lateral view a rounded plate with pair of short projections forming upper and lower lateral walls of slit.

Biology: The moths come to light and in the Galapagos, apart from one specimen collected at 169 m above sea level, all were found close to the sea shore, between February and April.

Distribution: This beautiful species is known to occur only on four of the Galapagos islands (Floreana, San Cristobal, Santa Cruz, and Seymour Norte) and Panama.

Remarks: *Aristotelia sarcodes* was described from a single male, deposited in the USNM and examined by BL (see label data above). The Galapagos specimens were identified with the help of Dr David Adamski (USNM).

### Gelechiini

***Chionodes*** Hübner, [1825]

A Holarctic and Neotropical genus containing 208 species in the Western Hemisphere (Hodges, 1999) and 20 in Europe (Karsholt & Riedl, 1996). One species has been found in the Galapagos (Schmitz & Landry, 2007). The host plant of this species is unknown but its species group feeds on Malvaceae.

***Chionodes stefaniae*** Schmitz & Landry, 2007 Fig. 4

*Chionodes stefaniae* Schmitz & Landry, 2007: 177–180, figs 1, 3–8.

Material examined: 20 ♂ (including holotype), 29 ♀ (For details see Schmitz & Landry, 2007).

Diagnosis: This species is superficially similar to many other *Chionodes* species and the characters to separate them are mentioned by Schmitz & Landry (2007). With regard to other Galapagos species of Gelechiidae, *C. stefaniae* is unique in its dark brown forewing pattern with a pair of off-white patches on costa and inner margin at 3/4 wing length.

***Stegasta*** Meyrick, 1904

*Stegasta* includes eight species in the Neotropical region and ten in Africa, Asia, and Australia (Becker, 1984; Beccaloni *et al.*, 2003). Robinson *et al.* (2007) record host plants mostly in the Fabaceae, but also in Bromeliaceae, Dipterocarpaceae, Lecythidaceae, and Oleaceae.

***Stegasta zygotoma*** Meyrick, 1917 Figs 5, 45, 46

*Stegasta zygotoma* Meyrick, 1917: 48. – Meyrick, 1925: 87. – Clarke, 1969b: 384, pl. 192 figs 3–3b. – Becker, 1984: 47. – Schmitz & Landry, 2007: 176.

*Gelechia bosquella* [sic] Chambers, 1875. – Schaus, 1923: 31, misidentification.

Material examined: 5 ♂. Male lectotype: 'Huigra, 4,500 ft., Ecuador, Parish. 6–14' [labels and dissection number not recorded] (BMNH). – *Santa Cruz*: Estacion Cientifica Charles Darwin. Deposited in CDRS and MHNG.

Diagnosis: The forewing markings of this species are unlike any others among the gelechiids recorded from the Galapagos, except *Stegasta francisci* sp. n., described below. The dorsally connected subbasal and median ochreous triangular patches and the patches of silver, shining scales at 1/10, 1/4, 1/2, and 2/3 are especially diagnostic of these two species. Within the genus, *S. zygotoma* resembles the new species described below, *S. comissata* Meyrick, 1923, and *S. bosqueella* (Chambers, 1875). It differs from *Stegasta francisci* sp. n. externally by the paler head, presence of dark brown at apex of labial palpus, and presence of three rings of paler, beige scales

towards the apex of the flagellum, i.e. the apical 2 flagellomeres are dark brown, the previous one is beige distally, the previous 3 are dark brown, the previous one beige distally, etc. The differences in genitalia are discussed below in the diagnosis of the new species. *Stegasta comissata* appears to be a smaller species as its lectotype is 8 mm in wingspan (10 mm for a paralectotype female) and that of zygotoma is 11 mm. In addition, the head of *S. comissata* is cream coloured, whereas that of *S. zygotoma* is brown with the scales mostly pale brown with their tips dark brown (in Galapagos specimens). The male genitalia of the lectotypes of these two species show some clear differences as illustrated by Clarke (1969b). With regards to *S. bosqueella*, based on specimens in the BMNH and one from Florida, *S. zygotoma* doesn't show obvious forewing differences, but the antennae of the former show 2–3 complete beige rings near the middle of the flagellum, followed by about 9 dark brown flagellomeres, followed by 4 beige rings each separated by 3 completely dark brown rings (or 1.5 dark brown flagellomere given the 2 rings of scales on each flagellomere). Based on Busck (1939) and a Florida specimen, the male of *S. bosqueella* shows obvious differences in, for example, an extra thin and curved projection ventrally on the valva at 1/3 from base and two cornuti in the vesica about half the size of those of *S. zygotoma*.

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=4) (Fig. 5): Head with ocelli. Scape without pecten. Flagellomeres mostly dark brown, first 13–14 with second row of scales beige ventrally, subsequent 4–5 with complete beige ring made of distal set of scales of each flagellomere, subsequent 9–10 entirely dark brown, following one with distal beige ring, followed by 3 dark brown flagellomeres, followed by one with distal beige ring, followed by 3 dark brown flagellomeres, followed by one usually with distal beige ring, followed by distal 2 dark brown flagellomeres. Forewing length: 4.7–5.0 mm. Segment VIII more strongly sclerotized, especially along ventral margins: sternum very large, about 2 X length of segment VII, with thin, reinforced basal margin slightly projecting anteriorly and with slight depression at middle, narrowing laterally and curving upward with denser scaling laterally, with apical margin almost straight, only very slightly depressed medially; tergum small, crescent shaped with broadly rounded ends, about half as narrow and slightly more than half as long as preceding tergum, basal margin broadly convex, strongly reinforced, and apical margin slightly rounded, almost straight.

Male genitalia (n=2) (Figs 45, 46). Uncus short, with pair of separate but close-set, narrow projections curved downward from middle at almost right angle, with apices rounded; also with pair of scoop-like, lateroapically directed, rounded pro - jections at base ventrally, with concave face facing laterally and opposing face adorned with setae of variable sizes, with three longer ones. Gnathos formed by pair of short, thin lateral arms. Tegumen short, about twice as long as uncus; with dorsal connection about 2/5 of whole length, strongly reinforced medially, posteriorly, and at straight anterior margins of wide arms. Valva about 1/4 longer than tegumen + uncus; base wider, forming narrowly rounded lobe in lateral view, reinforced dorsally at base; dorsal margin slightly convex; medial surface apically concave, with thick setae, ventroapically with one shorter and thicker spine directed medially, also with short and thin, sparse setation set mostly along one line along most of medial surface, shorter and denser at base; with short, pointed spine-like projection subapically on ventral margin,

directed downward. Transtilla mostly membranous and narrow, with short, narrow band of sclerotization medially. Vinculum bulky, about 2/5 length of valva and 1/5 wider than long, with anterior margin broadly rounded, with pair of thin bands of reinforcement from middle of posterior margin to sides of anterior margin. Sacculus processes as short, setose knobs joined laterally with medial bases of valvae. Phallus about 1/10 longer than valva, mostly lightly sclerotized, except for slightly enlarged, rounded base slightly projecting left, and narrow rod of reinforcement ventrally on right side; vesica with 2 large, curved, and pointed cornuti; ductus ejaculatorius with short, rounded, elongate area of sclerotization.

*Female*: Unknown to us.

BIOLOGY: The host plant is unknown. The moths come to light, and in the Galapagos specimens have been collected near sea level in March.

DISTRIBUTION: This species occurs in Colombia, Ecuador, and Peru between sea level and 3200 m according to the original description. In the Galapagos it has been found on the island of Santa Cruz only, at less than 20 m in elevation, on the site of the Charles Darwin Research Station.

REMARKS: *Stegasta zygotoma* was described from a series of 44 specimens from Colombia (Cali, 500 ft, and La Cumbre, 6600 ft), Ecuador (Huigra, 4500 ft), and Peru (Lima, [sea level], and Chosica, 2800 ft). Clarke (1969b: 384) designated the lectotype. The rest of the series should be investigated closely to determine if they all belong to *S. zygotoma* given the inconspicuous external differences found between the two Galapagos species.

The record of *Stegasta bosqueella* (Chambers) in the Galapagos (see Introduction and Schaus (1923)) is more probably attributed to this species than to the next because this record is from Santa Cruz Island, as are the available specimens of *S. zygotoma*, while the new species hasn't been found on this island.

***Stegasta francisci*** Landry, sp. n. Figs 6, 47, 48, 84

HOLOTYPE: ♂, 'ECU[ADOR]., GALAPAGOS | Isabela, n[ea]r Tagus Cove | 100 m elev[ation]., 21.v.1992 | M[ercury]V[apour]L[amp], leg[it]. B. Landry', 'HOLOTYPE | Stegasta | francisci | B. Landry'. Specimen in good condition, with some fringe scales of right hindwing missing, undissected. Deposited in MHNG.

PARATYPES: 7 ♂, 16 ♀ from Ecuador. – *Galapagos Islands, Fernandina*: 1 ♀ (dissected, slide MHNG ENTO 5954), SW side, G[lobal]P[ositioning]S[ystem]: 352 m elev[ation]., S 00° 20.503' W 091° 36.969', 10.ii.2005, u[ltra]v[iolet]l[ight] (B. Landry, P. Schmitz). – *Galapagos Islands, Floreana*: 1 ♂, 5 ♀ (one dissected, slide MHNG ENTO 6039), close to Las Palmas, GPS: elev. 131 m, S 01° 16.791', W 090° 28.274', 13.iv.2004, uvl (P. Schmitz); 3 ♂ (one dissected, slide MHNG ENTO 5953), 3 ♀ (one dissected, slide MHNG ENTO 5950), close to Las Palmas, GPS: elev. 154 m, S 01° 17.049' W 090° 28.305', 15.iv.2004, uvl (P. Schmitz). – *Galapagos Islands, Isabela*: 3 ♀, 8.5 km N P[uer]to Villamil, 11.iii.1989, M[ercury] V[apour]L[amp] (B. Landry); 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 5952), Alcedo, lado NE [side], 200 m [elev.], camp arida alta, 14.iv.2002, uvl (B. Landry, L. Roque); 1 ♂ (dissected, slide MHNG ENTO 5951), 1 ♀, V[olcan]. Darwin, 300 m elev., 20.v.1992, MVL (B. Landry); 1 ♀ (dissected, slide MHNG ENTO 5948), ± 15 km N Pto Villamil, 25.v.1992, MVL (B. Landry); 1 ♂, V. Alcedo, 1100 m elev., 13.x.1998, uvl (L. Roque). – *Continental Ecuador*: 1 ♂ (dissected, slide MHNG ENTO 6038), Manabi, Puerto Lopez, Hosteria Mandala, S 01° 32.955', W 80° 48.6176', 10 m elev., 24.iv.2006, uvl (P. Schmitz). Deposited in BMNH, CDRS, CNC, and MHNG.

ETYMOLOGY: The species name honours Jean-François Landry, eminent microlepidopterist based in Ottawa, Canada, for his precious collaboration during the process of elucidating the novel status of this taxon and all along the duration of this project, and for his friendship during these last 20 some years.

DIAGNOSIS: In habitus this species is similar to other species of *Stegasta*, notably *S. bosqueella* and *S. zygotoma*, as mentioned above under the diagnosis of *S. zygotoma*. The slight external differences between *S. zygotoma* and *S. francisci* are the darker head of the latter, its labial palpi with white apically, its darker antennae usually with 5 cream rings toward the apex, each separated by 3 dark brown scale rings, and without or almost without a white spot at the forewing apex. In male genitalia this species can be separated from *S. zygotoma* in its narrower and shorter median projections of the uncus, its longer, narrower, and straighter margined valva without an additional short spine at the ventral edge of the median surface apically, its longer phallus with a less bulky base, and by its four differently shaped cornuti on the vesica, as opposed to two large ones in *S. zygotoma*. In forewing pattern and that of the antennae and palpi, *S. francisci* is not distinguishable from *S. bosqueella*. The two can be separated in male genitalia easily, notably by the position of the subapical spine on the ventral edge of the valva, which is near the middle in *S. bosqueella*, the additional recurved projection at the base of the valva ventrally, absent in *S. francisci*, and the presence of two cornuti on the vesica, as opposed to four in *S. francisci*. Female genitalia of *S. zygotoma* were not available for comparison, but those of *S. bosqueella*, based on Busck (1939, fig. 60), do not have the semicircular projections at base of segment VIII ventrally, nor do they show a narrow sclerotized band on the dorsal wall of the ductus bursae, and the posterior part of the corpus bursae is much less strongly sclerotized.

DESCRIPTION: *Male* (n=8). Head dorsally with most scales narrow, greyish brown at their bases, dark brown at their apices; fronto-clypeus with scales dirty white. Haustellum greyish brown and dirty white. Maxillary palpus with dark brown, and white at tip. Labial palpus with basal segment dark brown; second segment mostly dark brown, furrowed ventrally, with white ring before middle, with some white scales dorsally posterior to white ring, and cream at apex dorsally; distal segment dark brown, with white to cream at base, medially as ring, and apex. Antennal scape without pecten, dark brown dorsally, dirty white ventrally, with white to cream (dorsally) apical ring; pedicel and flagellomeres mostly dark brown, first 12–15 flagellomeres with second row of scales partly cream ventrally, subsequent 2–5 with complete cream ring made of distal set of scales of each flagellomere, subsequent 10 entirely dark brown, followed by 5 cream rings each separated by 3 completely dark brown rings (or 1.5 dark brown flagellomere given the 2 rings of scales on each flagellomere) (rings indistinct in some specimens). Thorax mostly deep dark brown with bases of scales paler, sometimes with few narrow scales at base on each side of midline cream or chestnut brown; mesoscutellum cream to ochreous; metathorax pale greyish brown, shining. Foreleg mostly dark brown; tibia with 4 narrow bands of white scales, including one at apex; tarsomere I with white at base and apex; tarsomere II with white at apex only; tarsomeres III and IV entirely dark brown; tarsomere V mostly beige, with dark brown at base. Midleg femur brown, with some dirty white scales randomly

set; tibia dark brown with three small patches of white at base, 1/4, and 1/2, with white band at apex; tarsomere I, II, and V as on foreleg; tarsomeres III and IV with white apex. Hindleg femur with mixture of shining dirty white and pale greyish-brown scales; tibia dark brown, paler than fore- and midleg, with 4 white patches at base, 1/4, and bases of beige spines, also with dorsal crest of thin scales mostly brown; tarsomere I greyish brown with white at base and apices; tarsomeres II–V greyish brown at bases and beige towards apices, the latter colour increasing in importance on each tarsomere. Forewing length: 4.2–4.8 mm (holotype: 4.4 mm). Forewing background colour deep dark brown, with white as small patches on costa at 1/5 and middle, and sometime on midline at apex, and larger patch at 4/5; first costal white patch blending into first subbasal ochreous triangle opening on dorsum and connecting from dorsum with second, smaller ochreous triangle; with shining silver scaling at 1/10 above and below fold, as band in first ochreous triangle before and along its posterior margin, as large patch in middle around small dark brown discal spot, and at 2/3 below costal white patch until dorsum; fringe with basal set of scales greyish brown with darker brown tip, with second set of scales entirely greyish brown. Hindwing brownish grey with concolorous fringe. Abdomen dorsally greyish brown with paler, dirty white row of scales at apices of segments except for longer, thinner and uniformly greyish-brown scales over genitalia; ventrally grey, with white at base and on penultimate visible sternum; segment VIII more strongly sclerotized than preceding: sternum very large, about 4 X length of segment VII, with anterior margin forming pair of short bumps medially, laterally projecting and curving upward with denser scaling laterally, with apical margin depressed medially and poorly sclerotized; tergum small, shorter (by 1/3) and narrower than preceding tergum, with basal margin convex, more strongly sclerotized, with apical margin slightly rounded.

Male genitalia (n=3) (Figs 47, 48). Uncus short, with pair of separate but close-set, narrow projections curved downward with dorsal margin evenly rounded, with apices rounded; also with pair of scoop-like, lateroapically directed, rounded projections at base ventrally, with concave face facing laterodorsally and opposing face adorned with setae of variable sizes, with 2–3 longer ones, apically almost straight margined. Gnathos formed by pair of short, thin lateral plates. Tegumen short, about 2.5 X as long as uncus; with dorsal connection about 1/2 of whole length, strongly reinforced medially, posteriorly, and at straight anterior margins of wide arms. Valva narrow and about 3/10 longer than tegumen + uncus; base wider, not forming distinct lobe in lateral view, reinforced along base of dorsal margin; dorsal margin mostly straight, curved slightly upward in distal 1/5; medial surface apically concave, with thick setae, without distinct spine ventroapically, with short and thin, sparse setation along two lines on most of medial surface, but denser and shorter at base; with short, pointed spine-like projection subapically on ventral margin, directed downward and medially. Transtilla mostly membranous and narrow, with short, narrow, band of sclerotization medially. Vinculum bulky, almost half as long as valva and 1/2 wider than long, with anterior margin broadly rounded, with pair of thin bands of reinforcement from middle of posterior margin to sides of anterior margin. Sacculus processes forming short, setose knobs joined laterally with medial bases of valvae. Phallus long, about 1/5 longer than valva, mostly lightly sclerotized, except slightly enlarged,

rounded base slightly projecting left, and narrow ventral rod of reinforcement directed from middle at base and gently toward right side apically; vesica with one large, slightly curved and pointed cornuti, 2 smaller straight ones about 1/3 length of larger one, and another plate-like in two parts at right angle from each other and with rounded edges; ductus ejaculatorius with large oval area of sclerotization.

*Female* (n=16) (Fig. 6): Antenna slightly thinner than that of male; colour and forewing pattern as in male; frenulum with 3 acanthae. Forewing length: 3.4–4.6 mm. Segment VII unmodified, slightly longer than segment VI, tapering.

Female genitalia (n=5) (Fig. 84). Papillae anales short, lightly sclerotized, with sparse setation, with longer setae at base dorsomedially. Posterior apophyses thin, straight, long, almost reaching posterior margin of segment VII. Anterior apophyses straight, thin, about 1/5 length of posterior apophyses. Segment VIII at base with pair of flattened, semicircular projections about half as long as whole segment VIII, directed posteromedially, with dense scaling, and with short connections to posterior angles of ductus bursae; posterior parts of segment VIII with smooth, uniformly sclerotized surface, set back dorsad of basal, rounded projections. Ductus bursae strongly sclerotized, short, about 1.5 X as long as wide, with narrow sclerotized band in dorsal wall from almost anterior end of ductus bursae until about middle of segment VIII. Corpus bursae complex, about 3 X length of ductus bursae; enlarged base with strongly sclerotized, waved sheet on right side, with pair of short, lateral chambers dorsally; laterally on right with elongate sac slightly shorter than whole corpus; anteriorly ending in narrower, short circular sac adorned with pair of curved, pointed signa dorsally and ventrally; inception of ductus seminalis at posterior end of lateral membranous sac.

Biology: The host plant is unknown. The moths come to light, and in the Galapagos specimens have been collected between about 100 and 1100 m in elevation, between February and May, and in October. On Continental Ecuador, a specimen was collected near sea level (10 m) in April.

Distribution: This species was collected on the Galapagos Islands of Fernandina, Floreana, and Isabela as well as in the Province of Manabi, on Continental Ecuador.

## Gnorimoschemini

### ***Ephysteris*** Meyrick, 1908

The Western Hemisphere fauna of *Ephysteris* Meyrick (including synonyms *Microcraspedus* Janse, *Ochrodia* Povolný, *Echinoglossa* Clarke, and *Opacopsis* Povolný) (see Karsholt & Sattler (1998) and Li & Bidzilya (2008) for the generic synonymy, but Lee *et al*. (2009) consider *Microcraspedus* as valid) probably consists of four species. *Ephysteris fontosus* and *E. powelli* (Povolný, 1999) were described from California, and *E. trinota* (Clarke, 1965) from the Juan Fernandez Islands. Beccaloni et al. (2003) also record *E. jamaicensis* (Walsingham, 1897), but Becker (1984) mentions this species in *Phthorimaea* Meyrick while Povolný (1966: 145) synonymized the name with *E. subdiminutella* (Stainton, 1867) after a study of the types (see also Povolný, 2002). These four “New World” species, the 30 Palaearctic

species illustrated in Povolný (2002), the additional two Chinese species described by Li & Bidzilya (2008), and *E. longicornis* Clarke (1986), described from the Marquesas Archipelago were checked to make sure that our two Galapagos species were new.

Regarding *E. trinota*, no type designation was made in the original publication (Clarke, 1965). Two female syntypes were found in the USNM and examined by BL. Both were dissected, one by BL (slide N° "BL 1660 §"), bearing a red paratype label with the first three letters ("PAR") crossed in black ink, and the other by Clarke (No. 10,756), bearing a bluish grey paratype label. The slide of this latter paratype couldn't be located in the USNM (J. Brown, pers. comm. to BL). The female that BL has dissected is here designated lectotype. It bears the following labels: 'MASATIERRA | Cerro Alto | 1.II.1952 | 600 m | P. G. Kuschel' [white card stock, printed in black, with part of date and elevation handwritten in black ink, the elevation written sideways on right side], 'ATYPE | Echinoglossa | trinota | Clarke' [red card stock, handwritten in black except for printed 'ATYPE' before which 'PAR' (presumably) is crossed], '67936' [white lined paper, handwritten in blue ink], 'BL 1660 ♀' [green paper, handwritten in black ink], 'LECTOTYPE | Echinoglossa | trinota Clarke | Des. B. LANDRY' [red card stock, handwritten in black ink].

Our Galapagos host record in the Poaceae for *E. sporobolella* sp. n. is in accordance with the host plants of two other species of *Ephysteris*, while two more are detritivorous, one feeds on Asteraceae, one on Balanitaceae, and two on Zygophyllaceae (Robinson *et al.*, 2007).

***Ephysteris sporobolella*** Landry, sp. n. Figs 7–12, 49, 50, 85

HOLOTYPE ♂, 'ECU[ADOR]., GALAPAGOS | Santiago, Central, | 700 m elev[ation]., 9.iv.1992 | M[ercury]V[apour]L[amp], leg[it]. B. Landry', 'HOLOTYPE | Ephysteris | sporobolella | B. Landry". Specimen in excellent condition, undissected. Deposited in MHNG.

PARATYPES: 65 ♂, 80 ♀ from the Galapagos Islands, Ecuador. – *Baltra*: 3 ♂, 2 ♀, arid zone, 24.i.1989, M[ercury]V[apour]L[amp] (B. Landry). – *Española*: 1 ♂ (dissected, slide MHNG ENTO 4913), Bahia Manzanillo, 25.iv.1992, MVL (B. Landry); 1 ♂, same data except date, 29.iv.1992; 1 ♀ (dissected, slide MHNG ENTO 4914), Las Tunas Trail, 100 m elev[ation]., 30.iv.1992, MVL (B. Landry); 1 ♂, 1 ♀, Punta Suarez, 2.v.1992, MVL (B. Landry). – *Fernandina*: 1 ♂, 1 ♀, Cabo Douglas, G[lobal]P[ositioning]S[ystem]: S 00° 18.269', W 091° 39.098', 9.ii.2005, u[ltra]v[iolet]l[ight] (B. Landry, P. Schmitz); 1 ♂, SW side, GPS: 815 m elev., S 00° 21.270', W 091° 35.341', 14.ii.2005, uvl (B. Landry, P. Schmitz); 2 ♀, Punta Espinosa, 12.v.1992, MVL (B. Landry). – *Floreana*: 1 ♀, close to Las Palmas, GPS: elev. 154 m, S 01° 17.049', W 90° 28.305', 15.iv.2004, uvl (P. Schmitz); 1 ♀, Punta Cormoran, 21.iv.1992, MVL (B. Landry); 1 ♂, Las Cuevas, 23.iv.1992, MVL (B. Landry). – *Genovesa*: 3 ♀, Bahía Darwin, 10.iii.1992, MVL (B. Landry); 7 ♀ (1 dissected, slide MHNG ENTO 4918), same data except date, 25.iii.1992; 2 ♀, same data except date, 26.iii.1992. – *Isabela*: 1 ♀, Puerto Villamil, 2.iii.1989, MVL (B. Landry); 3 ♂, 4 ♀, 1 km W Puerto Villamil, 3.iii.1989, MVL (B. Landry); 1 ♂, 11 km W Puerto Villamil, 8.iii.1989, MVL (B. Landry); 2 ♂, 8.5 km N Puerto Villamil, 11.iii.1989, MVL (B. Landry); 1 ♀, 11 km N Puerto Villamil, 13.iii.1989, MVL (B. Landry); 1 ♂, NE slope Alcedo, near shore, GPS: 9 m elev., S 00° 23.619', W 90° 59.715', 29.iii.2004, uvl (B. Landry, P. Schmitz); 4 ♂, 2 ♀, NE slope Alcedo, near shore, GPS: 292 m elev., S 00° 23.829', W 91° 01.957', 30.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♂, NE slope Alcedo, near pega-pega camp, GPS: 483 m elev., S 00° 24.029', W 91° 02.895', 31.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♂ (dissected, slide MHNG ENTO 4917), Alcedo, lado NE, plaja, night on bushes, 13.iv.2002 (B. Landry); 1 ♂, 1 ♀, Alcedo, lado NE, 400 m [elev.], camp pega-pega, 15.iv.2002, uvl (B. Landry, L. Roque); 1 ♀, Alcedo, lado NE, 700 m [elev.], camp guayabillos, 16.iv.2002, uvl (B. Landry, L. Roque); 2 ♀ (1 dissected, slide MHNG ENTO 4916), Alcedo, lado NE, low

arid zone, bosq[ue]. palo santo, 18.iv.2002, uvl (B. Landry, L. Roque); 3 ♀, Tagus Cove, 13.v.1992, MVL (B. Landry); 1 ♀, V[olcan]. Darwin, 630 m elev., 16.v.1992, MVL (B. Landry); 1 ♀, same data except date, 17.v.1992. – *Marchena*: 1 ♀, [no precise locality] 12.iii.1992, MVL (B. Landry); 1 ♂, 1 ♀, [no precise locality] 23.iii.1992, MVL (B. Landry). – *Pinta*: 1 ♂, Plaja Ibbeston [sic], 13.iii.1992, MVL (B. Landry); 1 ♂, 1 ♀, arid zone, 15.iii.1992, MVL (B. Landry); 1 ♂, 1 ♀, Cabo Ibbetson, 8 m elev., N 00° 32.819', W 90° 44. 229', 15.iii.2006, uvl (P. Schmitz, L. Roque); 1 ♀, 200 m elev., 16.iii.1992, MVL (B. Landry); 1 ♂ (dissected, slide MHNG ENTO 5325), 18.iii.1992, MVL (B. Landry); 1 ♂, 1 ♀, ±50 m elev., 20.iii.1992, MVL (B. Landry); 1 ♀, ±15 m elev., 21.iii.1992, MVL (B. Landry). – *Pinzon*: 2 ♀, plaja Escondida, 20.iv.2002, uvl (B. Landry, L. Roque). – *Plaza Sur*: 1 ♀, [GPS]: 14 m elev., S 00° 34.982', W 90° 09.936', 15.iv.2006, uvl (P. Schmitz). – *San Cristobal*: 1 ♂, 4 km SE P[uer]to Baquarizo [sic], 12.ii.1989, MVL (B. Landry); 2 ♀, 1 km S El Progreso, 14.ii.1989, MVL (B. Landry); 5 ♂, 3 ♀, Pto Baquarizo [sic], 17.ii.1989, MVL (B. Landry); 1 ♂, 1 ♀, pampa zone, 18.ii.1989, MVL (B. Landry); 1 ♂, 4 km SE Pto Baquarizo [sic], 20.ii.1989, MVL (B. Landry); 1 ♀, base of Cerro Pelado, 22.ii.1989, MVL (B. Landry); 1 ♀, antiguo botadero, ca. 4 km SE Pto Baquerizo, GPS: 169 m elev., S 00° 54.800', W 89° 34.574', 25.ii.2005, uvl (B. Landry); 1 ♀, transition zone, SW El Progreso, GPS: 75 m elev., S 00° 56.859', W 89° 32.906', 15.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♂ (dissected, slide MHNG ENTO 4915), near Loberia, GPS: 14 m elev., S 00° 55.149', W 89° 36.897', 16.iii.2004, uvl (B. Landry, P. Schmitz). – *Santa Cruz*: 1 ♀, C[harles]D[arwin]R[esearch]S[tation], arid zone, 17.i.1989, MVL (B. Landry); 2 ♀, same data except date, 19.i.1989; 1 ♂, Barranco, 10 m elev., S 00° 44'34", W 90° 18'21", 26.i.2000, MVL trap (L. Roque, LR # 2000-01); 3 ♂, 6 ♀, littoral zone, Tortuga Bay, 29.i.1989, MVL (B. Landry); 1 ♂, 1 ♀, CDRS, arid zone, 3.ii.1989, MVL (B. Landry); 1 ♂, 1 ♀, Tortuga Res[erve]. W S[an]ta Rosa, 6.ii.1989, MVL (B. Landry); 1 ♂, E[stacion].C[ientifica].C[harles].D[arwin]., 7.iii.1992, uvl (B. Landry); 1 ♀, low agriculture zone, GPS: S 00° 42.132', W 90° 19.156', 13.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♂ (dissected, slide MHNG ENTO 5324), Finca Vilema, 2 km W Bella Vista, 1.iv.1992, MVL (B. Landry); 1 ♀, Bahía Conway, 14.iv.1992, MVL (B. Landry); 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 5326), ECCD, El Barranco, 22 m elev., S 00° 44.291', W 90° 18.107', 23.iii.2006, uvl (P. Schmitz); 1 ♂, E.C.C.D., 4.v.1992, yellow light (B. Landry); 1 ♂, Conway Bay, 30.vi.1999, Criada en *Sporobolus virginicus* (L. Roque); 2 ♂, C.D.R.S., Barranco, MVL, 11.xi.1999 (L. Roque). – *Santa Fe*: 2 ♀, Tourist trail, 28.v.1992, MVL (B. Landry). – *Santiago*: 1 ♂, La Bomba, GPS: 6 m elev., S 00° 11.151', W 090° 42.052', 1.iii.2005, uvl (P. Schmitz); 1 ♂, Cerro Inn, 28.iii.1992, MVL (B. Landry); 1 ♂ (dissected, slide MHNG ENTO 5353), 1 ♀, Bahia Espumilla, 4.iv.1992, MVL (B. Landry); 1 ♂, 200 m elev., 5.iv.1992, MVL (B. Landry); 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 4912), Aguacate, 520 m elev., 6.iv.1992, MVL (B. Landry); 1 ♂, same data as holotype. – *Seymour Norte*: 4 ♂, 1 ♀, Arid zone, 23.i.1989, MVL (B. Landry); 1 ♂ (dissected, slide MHNG ENTO 4925), 1 ♀, GPS: 17 m elev., S 00° 23.935', W 90° 17.369', 22.iii.2004, uvl (B. Landry, L. Roque, P. Schmitz); 1 ♀, GPS: 13 m elev., S 00° 24.013', W 90° 17.422', 23.iii.2004, uvl (B. Landry, L. Roque, P. Schmitz); 2 ♂, [no precise locality], 29.iii.1992, MVL (B. Landry). – *Wolf*: 1 ♂ (dissected, slide MHNG ENTO 4919), 2 ♀, N 01° 23.380', W 91° 49.201', 7.ii.2002, uvl (L. Roque, C. Causton). – Deposited in BMNH, CDRS, CNC, MHNG.

ETYMOLOGY: The specific name refers to that of the species' host plant, *Sporobolus virginicus* (L.) Kunth.

DIAGNOSIS: The habitus of this very variable species is best separated from that of *Ephysteris scimitarella* sp. n. by the usually distinctive forewing pattern with the area below the fold paler than the rest of the wing. Otherwise, the black markings are more conspicuous in this species, and it has only the subcostal vein and the cubital stem with an overlay of ochre-orange scales for any length, whereas *E. scimitarella* has most veins covered with similarly coloured scales. *Ephysteris sporobolella* can be separated from *E. scimitarella* in male genitalia more easily by the rounded uncus (vs. apically blunt), the more strongly produced subapical rounded lobes on the tegumen ventrally, the shorter gap between saccular processes (less than half length of valva (up

to 0.46) vs. more than half that length), and especially by the more simple apex of the phallus, without a strong spiniform projection on the right side. In female genitalia this species has a much shorter signum than that of *Ephysteris scimitarella* and its antrum is membranous whereas that of *E. scimitarella* is strongly sclerotized and long. In female genitalia *Ephysteris sporobolella* can be separated from the similar *E. trinota* Clarke by the smaller size (about 3/5 as long from tip of papillae to anterior end of anterior apophyses), the posteriorly converging versus diverging ventrolateral edges of segment VIII, the narrow crescent-shaped ventral edge of the ostium and membranous antrum versus a slightly concave posteroventral edge of the ostium with a long, well-sclerotized antrum (about 2 X as long as wide), the longer sclerites in the ductus bursae posterior to the connection with the ductus seminalis, and the shorter signum (about 1/2 as long). In male genitalia the differences appear subtle, except in the longer parabasal processes reaching 3/4 length of free part of valva, but only Clarke's (1965: 86) drawing of *trinota* is now available for comparison.

DESCRIPTION: *Male* (n=66) (Figs 7, 9, 12). Head with ocelli, mostly pure white with scales tipped brown except on frons and clypeus (holotype) to slightly off-white and/or more conspicuously tipped brown to dark brown, including frons and clypeus. Haustellum and maxillary palpus white, sometimes with brown-tipped scales. Labial palpus with basal segment white and brown; second segment laterally mostly brown with white at base, middle, and tip, sometimes all brown except for white tip of apical scales; terminal segment with white median third and sometimes also on one apical scale, brown to dark brown at base and apex. Antennal scape without pecten, mostly dark brown dorsally, sometimes appearing spotted white from visible white bases of scales, white ventrally; pedicel coloured as scape; flagellum dorsally brown, ventrally brown with white to ochre basal set of scales on each flagellomere. Thorax medially mostly white with some lightly brown-tipped scales, with dark brown basal set of scales and usually with black spot at apex of mesothorax, sometimes ochreous medially, especially on distal half, with or without black apical spot; tegulae mixed dark brown to ochre brown in variable percentages; metathorax pale greyish brown. Foreleg coxa mostly white with some brown-tipped scales or mostly dark brown; femur mostly dark brown with white bases of scales more or less apparent and with some white scales; tibia as femur, with white spots at base of epiphysis and apex; tarsomeres I–IV as femur but with apical white rings, tarsomere V dark brown. Midleg mostly white, with few brown scales on femur, tibia, lateral tibial spine, and bases of distal tarsomeres; sometimes mostly dark brown with white bases of scales more or less apparent and with some white scales, with white spots or rings on tibia at base of epiphysis and apex and on tarsomeres I–IV at apices. Hindleg mostly white with few brown scales on tibia laterally, on lateral spines, and at base of dorsal crest of thinner scales, and dorsally at bases of tarsomeres; sometimes with more dark brown scaling on all parts with, for example, tarsomeres only with apical white rings. Forewing length: 2.8–3.9 mm (holotype: 3.6 mm). Forewing mostly greyish brown on costal half, with paler costa and wider band on distal half of costa, with most scales more or less widely tipped brown, also with chestnut-brown line along Sc at base, along fold, and along midline distally, with black spot in fold at 1/3, and usually also below midline postmedially, and often along midline subapically and at apex, with area below costal

fold paler than above, with few brown-tipped scales; sometimes whole wing darker greyish brown, with black line in fold at base and stronger black spots; darker specimens sometimes with more contrasting chestnut-brown lines as above, with additional lines or spots on dorsum postbasally, at apex of fold, and as scattered scales; fringe mostly greyish brown, with basal scales more or less clearly white based and with brown tip more or less strongly marked. Hindwing greyish brown, with concolorous fringe. Abdomen dorsally greyish brown, with yellowish spine-like scales on tergum II and base of third; ventrally mostly white with some scales brown to greyish brown. Segment VIII with tergum slightly longer than preceding tergum, with basal margin reinforced, thin, straight, with lateral margins parallel sided until middle, then broadly convex; sternum wider than long, about as long as tergum, margins not reinforced, with apical margin medially concave, shallowly rounded, with each side narrowly rounded.

Male genitalia (n=8) (Figs 49, 50). Uncus short, dorsally slightly concave, lateral margins converging, apically rounded, slightly conical, setation short and sparse, along edges; lateral arms terminating in broad, shallow V or U opening posteriorly, with ventral branch often slightly longer. Gnathos arms about half as long as median hook, straight, usually with two, short, triangular dorsal projections postbasally and subapically; gnathos hook with arms separated at base for only 1/4 their length, gently curved at base, then almost straight, apex enlarged dorsally and sometimes also slightly ventrally, dorsoapically with irregular surface, sometimes with 1–2 more or less well-defined hooks, without setae. Tegumen long and narrow, slightly more than 4 X as long as uncus, dorsal connection 2/3 length of tegumen, dorsally flat with median sclerotized bar along middle third and sometimes also toward apex, in dorsal view with lateral margins slightly converging from base to before middle, then margins almost straight to apex, ventrally at apex with short lateral arms projecting underneath lateral arms of uncus; ventrally, before apex, with rounded lobes almost meeting midventrally; pedunculi short, slightly less than 1/3 length of whole tegumen. Valva curving inward and downward, almost reaching apex of tegumen, very slightly enlarged subapically, then tapering to rounded apex, with dense line of short setae along distal 1/2 of dorsolateral edge, except apically, and more sparse longer setae on ventral surface on distal 1/3. Parabasal process slightly curved downward, slightly flattened laterally, with few short setae apicoventrally, almost half as long as free part of valva, with apex rounded. Sacculus processes short, more or less distinctly separated in narrow ventral part and slightly narrower and longer dorsal part (to very distinct parts of equal lengths), with short setae mostly along edges of two parts, separated by U-shaped median gap about 2/5 (0.36–0.46) length of valva. Vinculum narrow; saccus mostly straight, sometimes slightly enlarged subapically, half as long to 3/5 length of phallus, variable in width (0.1–0.2 length of saccus, measured apically). Phallus straight in dorsal view, about as long as saccus + parabasal processes; lateroventrally on right side with more strongly sclerotized bar from base of coecum to apex; distal 1/3–1/4 dorsally open (membranous); apex sometimes slightly more produced on right side and slightly bent, sometimes with tiny pointed or rounded projection on right edge subapically; coecum with lateral margins equally rounded, with ventral margin slightly produced; vesica spiculose, without cornuti.

*Female* (n=80) (Figs 8, 10, 11): Antenna thinner than male's. Frenulum generally with 3 acanthae, sometimes with 2. Forewing length: 2.6–4.6 mm. Segment VII slightly longer than preceding, narrower, not distinctly reinforced at margins, with apical margin of sternum shallowly excavated medially, rounded, with apical margin of tergum straight.

Female genitalia (n=5) (Fig. 85). Papillae anales in lateral view somewhat egg shaped, with setation sparse, mostly short and set along ventral edge and apex, with 3 or 4 longer setae along basal margin and at apex, with microspicules on ventral margin and apex, with poorly sclerotized, often indistinct bar at connection of posterior apophyses. Posterior apophyses straight, long, reaching slightly beyond ostium in extension, with slight swelling at connection with apex of intersegmental membrane VIII–IX. Anterior apophyses straight or slightly curved outward, about half as long as posterior apophyses, connected with moderately sclerotized and narrow, crescent-shaped ventral edge of ostium bursae. Segment VIII narrow, narrowly membranous ventrally and broadly so dorsally, with ventrolateral edges posteriorly diverging, without microsculpture, with ventral membrane spiculate, laterally not tapering towards membranous dorsal gap, with few short setae on apical margin towards dorsal end of sclerotized part. Antrum membranous. Ductus bursae without spicules, posteriorly narrow and membranous for 1/10 of whole length, then sclerotized for about 3/10 of whole length, next 1/10 membranous and narrow, anterior half membranous and twice as wide as posterior one. Inception of ductus seminalis at 4/10. Corpus bursae circular, about as long as ductus bursae, with microspicules at posterior end only; signum trifid, with longitudinal element pointed at both ends, with two anterolateral points connected to wall of corpus bursae.

BIOLOGY: This species was reared in the Galapagos on *Sporobolus virginicus* (L.) Kunth (Poaceae). The moths come to light and were collected mostly at low elevations, in the littoral zone, but also occasionally higher up, such as 700 m on Alcedo, Isabela Island, and 815 m on Fernandina. Based on available specimens adults fly during the first six months of the year, and in November.

DISTRIBUTION: Probably endemic, this is the most commonly encountered species of Gelechiidae on the archipelago. It has been found on 15 of the 19 Galapagos islands of more than 1 $km^2$, i.e. Baltra, Española, Fernandina, Floreana, Genovesa, Isabela, Marchena, Pinta, Pinzon, San Cristobal, Santa Cruz, Santa Fe, Santiago, Seymour Norte, and Wolf, as well as on the tiny island of Plaza Sur (0.119 $km^2$).

REMARKS: The variation in the forewing pattern and colour and shape of the saccus in this species is not unique as a similar variation was mentioned also in the description of *Ephysteris powelli* (Povolný, 1999), and *E. subdiminutella* (Stainton) is also very variable (see below). The variation in length of valva and shape of saccus are not correlated in seven specimens compared, i.e. specimens with longer valvae have a longer saccus, but the latter may be narrow or wide, and specimens with short valvae may have a short or long saccus, but the latter is narrower.

***Ephysteris scimitarella*** Landry, sp. n. Figs 13, 51, 52, 86

HOLOTYPE: ♂, 'ECU[ADOR]., GALAPAGOS | Santa Crúz, Los | Gemelos, 27.v.1992 | M[ercury]V[apour]L[amp], leg[it]. B. Landry', 'HOLOTYPE | Ephysteris | scimitarella | B.

Landry", 'MHNG | ENTO ♂ | 00005352', 'genitalia slide | BL 1166 ♂' [green, upside down]. Specimen in excellent condition; slide preparation as well, except for sternum VIII, which is detached and folded on itself. Deposited in the MHNG.

PARATYPES: 1 ♂, 4 ♀ from the Galapagos Islands, Ecuador. – *Marchena*: 1 ♀ (dissected, slide MHNG ENTO 4927), [no specific locality], 23.iii.1992, M[ercury]V[apour]L[amp] (B. Landry). – *San Cristobal*: 1 ♀ (dissected, slide BL 1669), pampa zone, 18.ii.1989, MVL (B. Landry). – *Santa Cruz*: 1 ♂ (dissected, slide MHNG ENTO 4907), 2 ♀ (1 dissected, slide MHNG ENTO 4926), same data as holotype. Deposited in CDRS, CNC, MHNG.

ETYMOLOGY: The species name refers to the scimitar-schaped signum in the female corpus bursae.

DIAGNOSIS: This species is characterized in forewing pattern by a uniform background of off-white, brown-tipped scales, with two small black spots and the veins marked with orange-ochre scales. One of the other Galapagos species of *Ephysteris*, *E. sporobolella*, has similar background scaling, but orange ochre only on the cubital stem and the subcostal vein, while the anal sector, below the fold, is clearly paler than the rest of the forewing. In genitalia the two species also differ as mentioned above in the diagnosis of *Ephysteris sporobolella*. *Phthorimaea perfidiosa* Meyrick is also similar in forewing pattern, but this species doesn't have the dark brown spots in the fold and both sexes lack the distinct tuft of scales ventrally on the second segment of the labial palpus.

DESCRIPTION: Male (n=2) (Fig. 13). Head with ocelli, off-white, with most scales tipped brown. Haustellum off-white; maxillary palpus off-white, tipped brown. Labial palpus with basal segment off-white; second segment with tuft of scales projecting ventroapically, dorsally off-white, medially off-white at base and mostly greyish brown on distal 1/3, laterally with most scales off-white tipped dark brown to brown toward apex; third segment mostly dark brown, with off-white at base and middle. Antennal scape without pecten, dark brown with off-white at base of scales and with yellowish-white patch apically; pedicel and flagellum dark brown to brown toward tip, with pedicel and basal ca. 15 flagellomeres with basal set of scales partly forming yellowish-white patch. Thorax at base medially with off-white, brown-tipped scales, including on tegulae on medial edges; tegulae mostly ochre orange (holotype), or as base of thorax medially; metathorax greyish white. Foreleg with off-white, brown-tipped scales; paler on coxa (more off-white than brown); darker on tibia and darkest on tarsomeres, with off-white patches on tibia postmedially and apically and at apex of each tarsomere. Midleg coxa off-white with greyish brown; femur, tibia, and first tarsomere with scales half off-white and half brown; tarsomeres II–V increasingly darker brown; with off-white patches at tips of tibia and tarsomeres. Hindleg as in foreleg although paler, with crest of off-white hair-like scales on dorsal edge of tibia and contrasting dark brown tibial spines; tarsomeres darker brown at their bases. Forewing length: 4.2–4.7 mm (Holotype 4.7 mm). Forewing with off-white, brown-tipped scaling on most of surface, with overlay of orange-ochre scales of variable shades on veins, and along side veins and anal sector on basal half; with beige, narrower scales on distal half of costa; with two black dots in fold at 1/3 and above fold slightly beyond 1/2; fringe's scales off-white and brown tipped, hairs greyish brown. Hindwing greyish brown with concolorous fringe. Abdomen mostly greyish brown

dorsally, terga II and III ochre, with short, pointed scales; ventrally mostly off-white, with few brown specks; sternum VIII narrowing toward apex, with apical margin concave; tergum VIII shorter and narrower than tergum VII, with basal and lateral margins forming narrow, strongly sclerotized bands, median area poorly sclerotized, apical margin rounded.

Male genitalia (n=2) (Figs 51, 52). Uncus short, dorsally slightly concave, lateral margins slightly converging, apically blunt with few short setae; lateral arms terminating in short V opening posteriorly, holotype with ventral branch of V longer, thumb-like. Gnathos arms about half as long as median hook, straight, with two short, triangular dorsal projections postbasally and subapically; gnathos hook with arms only shortly separated at base, gently curved to less than right angle, apex enlarged dorsally with short, rounded projections dorsally, without setae. Tegumen long and narrow, almost 4 X as long as uncus, dorsal connection 2/3 length of tegumen, dorsally flat with median sclerotized bar along median third, in dorsal view with lateral margins slightly converging from base to before middle, then margins slightly diverging to apex, margins ventrally before apex with low, rounded projection, ventrally at apex with short, blunt lateral arms projecting underneath lateral arms of uncus; pedunculi slightly less than 1/3 length of whole tegumen. Valva curving inward and downward, almost reaching apex of tegumen, slightly enlarged subapically, then tapering to narrowly rounded apex, with dense line of short setae along distal 1/2 of dorsolateral edge and more sparse longer setae along midline of lateral surface on distal 1/3. Parabasal process slightly curved downward, with few short setae medially on slightly enlarged distal 2/5, slightly longer than 1/2 valva, with apex rounded. Sacculus processes short, roughly separated in broadly rounded ventral part and slightly narrower and longer dorsal part, with short setae mostly along edges, separated by long, narrow, U-shaped median gap slightly longer than 1/2 length of valva. Vinculum narrow; saccus straight, about 3/5 length of phallus, narrow (0.1 length of saccus, measured apically). Phallus straight in lateral view, about as long as saccus + parabasal processes; ventrally with more strongly sclerotized bar from base of coecum on right side to apex in middle and on left side, on each side of short, ventral, U-shaped gap; distal 1/4 dorsally open (membranous); apex with left lateral wall curved downward and rounded, with right side less strongly sclerotized at base of strongly sclerotized spiniform projection directed apicolaterally at half right angle; çoecum with right margin broadly rounded and left margin straight; vesica spiculose, without cornuti.

*Female* (n=4): Antenna slightly thinner than in male; colour as in male. Frenulum with 3 acanthae. Forewing length: 4.9–5.9 mm. Abdomen without modified scales on terga II and III; segment VII about 1/2 longer than preceding segment, apical margin of sternum broadly concave, that of tergum straight.

Female genitalia (n=3) (Fig. 86). Papillae anales in lateral view conical, with apex rounded, setation sparse, mostly along ventral edge and apex, with two longer setae at base toward dorsal margin, with microspicules toward apex, with short sclerotized, perpendicular bar at connection of posterior apophyses. Posterior apophyses straight, long, reaching beyond ostium in extended position, with slight swelling at connection with apex of intersegmental membrane VIII–IX. Anterior apophyses straight, slightly shorter that half as long as posterior apophyses, connected with

strongly sclerotized, narrow ventral edge of ostium bursae. Segment VIII wide, broadly membranous ventrally, without microsculpture, with ventral membrane spiculate, laterally tapering toward membranous dorsal gap, with few short setae on apical margin towards dorsal end of sclerotized part. Antrum strongly sclerotized, narrow, elongate, reaching anterior ends of anterior apophyses, formed by two twisted sclerites, the left one curved ventrally and the right curved dorsally, both forming narrow bump dorsally and ventrally before anterior end. Ductus bursae short and wide, about as long as antrum and as wide as base of antrum, without spicules; ductus seminalis inserted at posterior end, before antrum. Corpus bursae rounded, slightly elongate, slightly longer than antrum + ductus bursae, with spicules on most of inside surface; long, keel-shaped signum with very narrow base, ending in three points, the median one slightly projecting inside bursa.

BIOLOGY: Unknown except for the fact that moths come to light and have been found at sea level, at an elevation of 580 m (Los Gemelos), and in the pampa zone (probably above 600 m), in February, March and May.

DISTRIBUTION: This species is known only from the Galapagos islands of Marchena, San Cristobal, and Santa Crúz.

REMARKS: A long signum in the female corpus bursae was not observed in any of the other verified members of the genus (See Remarks above concerning *Ephysteris sporobolella* sp. n.).

***Ephysteris subdiminutella*** (Stainton, 1867) Figs 14, 53, 54, 87

*Phthorimaea subdiminutella* Stainton, 1867: 145.
*Gelechia jamaicensis* Walsingham, 1897: 76.
*Phthorimaea jamaicensis* (Walsingham). – Becker, 1984: 46.

MATERIAL EXAMINED: 2 ♂, 1 ♀ collected on the Galapagos Islands. – *Plaza Sur*: 1 ♀ (dissected, slide MHNG ENTO 5991), S 00° 34.980', W 90° 09.990', 18 m elev[ation]., u[ltra]v[iolet]l[ight]. – *Santiago*: 2 ♂ (one dissected, slide MHNG ENTO 4929), La Bomba, S 00°11.151', W 090°42.052', 6 m elev. Deposited in CDRS and MHNG.

DIAGNOSIS: This is a highly variable species with several forms of forewing colour and pattern (Povolný, 1966, 2002), but the three Galapagos specimens are all very similar (see Fig. 14). The forewing length varies between 3.6 and 6.3 mm (Povolný, 2002), but the Galapagos specimens have a forewing length between 3.5 and 3.6 mm for the males, and 3.2 mm for the female. The male genitalia are characterized by the parabasal processes being almost as long and as thick as the valvae themselves (Fig. 53). In female genitalia the signum forming a short hook arising from a triangular plate is characteristic (Fig. 87). In the Galapagos this species is most similar to *Agnippe omphalopa* (Meyrick), *Phthorimaea absoluta* Meyrick, and *Scrobipalpula densata* Meyrick. A comparison of genital features is the only way to arrive at an accurate determination.

BIOLOGY: Several host plants are known in *Balanites*, *Tribulus*, and *Zygophyllum* (Zygophyllaceae) and *Zizyphus* (Rhamnaceae) (Povolný, 2002). The caterpillar first mines a tunnel and then a ramified blotch. Often several leaves are attached. Pupation occurs outside the mines (Povolný, 2002).

DISTRIBUTION: Widely distributed in the Palaearctic region, where it possibly originated, this species is believed to have been introduced to the Western Hemisphere

(Povolný, 1966). It is also known from India and Australia (Povolný, 2002). In the Galapagos it has been collected so far only on Plaza Sur and Santiago, near the sea shore.

REMARKS: This species was described at least 15 times and for a complete synonymy one can refer to Povolný (2002). Following the description of synonym *E. jamaicensis* (Walsingham) this species is recorded here for the second time only from the Western Hemisphere.

The Galapagos specimens were identified on the basis of genital illustrations provided by Povolný (2002), i.e. six drawings for males and five for females.

The species is known as the caltrop moth in Australia (www.ento.csiro.au).

***Phthorimaea*** Meyrick, 1902

Povolný (1994: 8) writes that *Phthorimaea* 'perhaps includes only two distinct species, viz. *P. robusta* [Povolný]..., and *P. operculella*', and in his checklist of Neotropical species (1994: 10), he lists four species, omitting *P. perfidiosa* Meyrick and the synonyms of *P. operculella*.

*Tuta* Kieffer & Jörgensen, 1910, was recently resynonymized with *Phthorimaea* (Lee *et al*. 2009), following Hodges & Becker (1990) and Karsholt & Sattler (1998). Povolný (1994) disagreed with that synonymy, considering *Tuta* as a valid genus. *Phthorimaea absoluta* was not specifically mentioned by Lee *et al*., but Lee confirmed that it belongs with *Phthorimaea* (pers. comm. to BL).

In the broad sense, as taken here, *Phthorimaea* is a Neotropical genus that includes 13 species (Povolný, 1994), including two that are now also distributed in the Old World. The host plants of the larvae are mostly Solanaceae, but also Brassicaceae, Myrtaceae, Poaceae, Rubiaceae, and Typhaceae (Robinson *et al*., 2007).

***Phthorimaea perfidiosa*** Meyrick, 1917 Figs 15, 16, 55, 56, 88

*Phthorimaea perfidiosa* Meyrick, 1917: 41, 42. – Meyrick, 1925: 93. – Povolný, 1989: 93.
*Gnorimoschema perfidiosa* (Meyrick). – Clarke, 1969b: 160, figs 3–3b. – Becker, 1984: 46.

MATERIAL EXAMINED: 13 ♂, 7 ♀. Male lectotype (dissected, slide 5828, Clarke), "La Crumbre [sic], Colombia P. 6,600 ft. 5–14." (BMNH). – *Fernandina*: Cabo Douglas, S 00° 18.269' W 091° 39.098'. – *Genovesa*: Bahía Darwin. – *Isabela, Darwin*: Tagus Cove. – *Isabela, Sierra Negra*: 1 km W Puerto Villamil. – *Pinta*: arid zone; ±15 m elev. – *Santa Cruz*: Estacion Cientifica Charles Darwin. – *Santiago*: Cerro Inn. Deposited in BMNH, CDRS, CNC, and MHNG.

DIAGNOSIS: Among Galapagos Gelechiidae this species can be separated by its greyish-brown forewing with a poorly contrasted pattern of chestnut brown along the veins, sometimes with a small dark brown spot in the fold submedially, and rarely with another smaller dark brown spot above it in the cell. *Ephysteris scimitarella* sp. n. has a similar wing pattern although its forewing has a dark brown spot in the fold at 1/3 and another above the fold slightly beyond middle, and both sexes have the second segment of the labial palpus adorned with a distinct tuft of scales ventrally. *Phthorimaea absoluta* Meyrick has a similar pattern but the forewing is darker brown and the chestnut markings of the forewing are not restricted to fine longitudinal lines; there are often spots instead of lines, especially in the middle of the wing. The males of *P. perfidiosa* are easier to separate because of their elongate tergum VIII covered with

narrow, whitish beige, partly erect scales and flanked by a pair of concolorous coremata barely reaching the apex of the tergum (Fig. 16). *Phthorimaea perfidiosa* is similar to *P. operculella* (Zeller, 1873) a widespread pest of potato, including in the shape of the male's tergum VIII. The former can be separated from the latter by its smaller size (forewing length of *P. operculella* ca. 7 mm). The male genitalia of *P. perfidiosa* differ mainly in the less strongly developed sacculus processes, only slightly produced ventroapically and slightly shorter than the parabasal processes, the latter forming a short, strongly sclerotized hook. In *P. operculella* the sacculus processes form distinct projections with a short, curved tip (see Zimmerman, 1978: 77, fig. 30), and the parabasal processes are shorter rounded projections. Also, the fold between the sacculus processes is long and narrow with parallel margins whereas that of *P. operculella* is broader anteriorly, narrower subapically, and broadly opening posteriorly. The gnathos of *P. perfidiosa* is circular whereas that of *P. operculella* is slightly elongate, tongue shaped. In female genitalia the anterior apophyses extend anteriorly beyond the sclerotized section of the ductus bursae in *P. operculella* whereas they barely reach it in *P. perfidiosa*. The posterior apophyses also are longer in *P. operculella*, reaching the anterior end of the sclerotized section of the ductus bursae, whereas in *P. perfidiosa* they reach the middle of the sclerotized section of the ductus bursae.

Additions to original Description: *Male* (n=12) (Figs 15, 16): Head with ocelli. Scape without pecten. Forewing length: 3.5–4.5 mm. Sternum VIII elongate, as long as two preceding abdominal segments, all equally sclerotized, with straight base, narrowly rounded apically; tergum VIII as long as sternum, tongue shaped, with membranous basal 1/3, with strongly concave base.

Male genitalia (n=5) (Figs 55, 56). Uncus with apical margin straight or slightly depressed medially, with 3 microsetae widely spaced on each side; apical angles rounded; lateral margins very slightly projecting laterally and downward, rounded; with pair of patches of about 9 microtrichiae dorsally on each side toward apex. Gnathos circular, covered with small spines, with lateral margins strongly reinforced on basal half; apex broadly rounded, not upturned. Tegumen long and narrow, dorsal connection about 3/5 length of whole tegumen, dorsally slightly depressed before middle, with base dorsally and dorsal part of basal arms covered with spinules. Valva long and narrow, apical 1/10 reaching beyond uncus, enlarged, and bent medially and downward at about half right angle; with apex more strongly sclerotized, devoid of setae, and pointed. Sacculus processes only slightly produced ventroapically and shorter than parabasal processes. Latter forming short, strongly sclerotized hook. Vinculum slightly concave, rectangular, about 2/5 length of tegumen + uncus, with lateral margins reinforced, parallel sided, with apical margin slightly convex, rounded. Phallus narrow, about 1/10 shorter than length of whole genital capsule, upcurved, subbasally expanded laterally and dorsally, with narrower, rounded base; ventrally reinforced by pair of rods, the left one ending subapically, the right one apically ending in right, spoon-shaped wall; apex with two short, narrow, curved 'cornuti.'

*Female* (n=7): Antenna thinner than male's; colour and forewing pattern as in male; hindwing without hair pencil on costa; frenulum with 3 acanthae; forewing length: 4.2–4.7 mm. Segment VII unmodified, longer and narrower than segment VI.

Female genitalia (n=3) (Fig. 88). Papillae anales elongate, lightly sclerotized, setation sparse with few longer setae mediodorsally at base. Posterior apophyses thin, straight, and long, reaching about 1/3 length of anterior apophyses. Anterior apophyses about half as long as posterior apophyses and slightly thicker, mostly straight, slightly curved upward and bent inward at their apices. Segment VIII ventrad of ostium forming short plate with straight apical margin, with short, posteriorly directed spine-like projection on each side laterally; inner wall anteromedially with microsculpture of pentagons changing into spinules toward posterior margin. Segment VIII dorsad of ostium medially unsclerotized and spiculose, forming dorsal wall of funnel, laterally with two wide, apically narrowing, strongly sclerotized plates with rich microsculpture of pentagons except on narrower lateroapical apices. Ductus bursae strongly sclerotized, long, reaching slightly beyond anterior apophyses, anteriorly with membranous gap followed by short, subquadrate ventral plate laterally more strongly sclerotized. Inception of ductus seminalis at posterior end of corpus bursae, behind connection with ductus bursae. Corpus bursae elongate, about 1/3 longer than ductus bursae, slightly wider at anterior end; signum curved, narrow, spine-like, situated ventrally and at 1/3 from posterior end.

BIOLOGY: Unknown except that the species was found in the Colombian Andes at about 2200 m and in the Galapagos mostly at sea level. The moths are attracted to light and in the Galapagos specimens were collected in February, March, and May.

DISTRIBUTION: Colombia and Ecuador; Galapagos islands of Fernandina, Genovesa, Isabela, Pinta, Santiago, and Santa Cruz.

REMARKS: The widespread *Phthorimaea operculella* Meyrick, a notorious pest of potato and other Solanaceae, has not yet been reported in the Galapagos, but its eventual presence is likely.

***Phthorimaea absoluta*** Meyrick, 1917 Figs 17, 57, 89

*Phthorimaea absoluta* Meyrick, 1917: 44.
*Gnorimoschema absoluta* (Meyrick). – Meyrick, 1925: 91. – Clarke, 1965: 80, fig. 80. – Clarke, 1969b: 143, figs 1–1b.
*Scrobipalpula absoluta* (Meyrick). – Povolný, 1967: 125. – Becker, 1984: 47.
*Scrobipalpuloides absoluta* (Meyrick). – Povolný, 1987: 69.
*Tuta absoluta* (Meyrick). – Povolný, 1994: 9, 10. – Causton *et al.*, 2006: 140. – en.wikipedia.org (checked October 5, 2009). – www.tutaabsoluta.com.

MATERIAL EXAMINED: ♂, ♀. Male holotype, described from Huancayo, Peru [labels and dissection number not recorded] (BMNH). – *Fernandina*: Cabo Douglas, S 00° 18.269' W 091° 39.098'; SW side, 815 m elev., 00° 21.270' W 091° 35.341'. – *Isabela, Sierra Negra*: ±15 km N Puerto Villamil. – *San Cristobal*: Puerto Baquerizo, larva minador hojas *Solanum tuberosum*. Deposited in CDRS and MHNG.

DIAGNOSIS: This species is similar to its congener, *P. perfidiosa* and to *Scrobipalpula densata* (see Diagnosis of these species, above and below). The male is especially easy to separate as it doesn't show the specialized features of tergum VIII found in the two above-mentioned species.

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=3) (Fig. 17): Head with ocelli. Scape without pecten. Forewing length: 4.1 mm. Abdomen without terminal hair

pencils. Tergum VIII slightly longer and narrower than sternum VII, with narrow, strongly sclerotized, evenly concave basal margin, with lateral margins parallel and apical angles rounded, with apex straight. Sternum VIII wider and slightly longer than sternum VII, with basal margin slightly concave in middle, not reinforced, lateral margins rounded, and apex straight.

Male genitalia (n=2) (Fig. 57). Uncus quadrangular, with apical margin straight, with lateral angles slightly produced as short triangles; dorsum slightly depressed in middle, with about 12 microsetae apicolaterally; lateral margins slightly converging and rounded. Gnathos with lateral margins strongly sclerotized, parallel, with dorsal, triangular projection near middle, joining in pointed, upturned apex; dorsal membrane poorly spiculose. Tegumen long, dorsal connection 3/5 length of whole tegumen, with slight lateral constriction at about 2/3 length of dorsal connection; dorsally flat; without spinules. Valva long and narrow, basal 2/5 strongly sclerotized, apical 3/5 slightly directed ventrally, apically enlarged, rounded, and directed medially. Saccular processes strongly sclerotized, widely separated in broad V, laterally compressed with ventral hump in ventral view, square in lateral view, with short setation laterally on hump and apicodorsal angle, latter with short spine at apicodorsal angle. Parabasal processes as small digit-like knobs with 2–4 apical setae slightly longer than processes. Vinculum slightly concave, elongate and narrow, about 2/3 length of tegumen + uncus, with lateral margins reinforced, parallel sided, with apical margin slightly rounded. Phallus narrow and straight, about as long as whole genital capsule; base slightly enlarged, rounded, with slight downward angle from shaft; shaft with short spine-like projection ventrally on right side at 4/5; ventrally reinforced by pair of rods; apically with left wall spoon shaped, right wall narrower; apex with one narrow, curved 'cornutus' about 1/10 length of whole phallus.

*Female* (n=2): Antenna thinner than male's; colour, and forewing pattern as in male; frenulum with 3 acanthae; forewing length: 4.3–4.5 mm. Segment VII unmodified, longer than segment VI and gently tapering to about 2/3 basal width; apical margin straight.

Female genitalia (n=2) (Fig. 89). Papillae anales short, lightly sclerotized, setation sparse with few longer setae mediodorsally at base. Posterior apophyses thin, straight, and long, about 5 X length of papillae anales and reaching slightly beyond ostium bursae. Anterior apophyses about 1/3 length of posterior apophyses, slightly thicker, straight or slightly curved inward, directed slightly upward, apically not bent. Segment VIII ventrad of ostium undifferentiated, ventral lip of ostium situated in intersegmental membrane VII–VIII; dorsad of ostium medially with pair of spinulose, separate troughs converging at mid-length, lateral plates with thick sclerotization only along rounded medial-apical margins, without special microsculpture, with 5–6 setae at apicolateral angles; dorsally membranous. Ductus bursae strongly sclerotized, long, slightly tapering anteriorly, reaching slightly beyond anterior apophyses, anteriorly with short membranous section. Inception of ductus seminalis at posterior end of corpus bursae, behind connection with ductus bursae. Corpus bursae elongate, about 1/2 longer than ductus bursae and 1/4 as wide, forming elongate oval; straight, narrow spine-like signum situated ventrally and at 1/3 from posterior end.

BIOLOGY: The tomato leaf miner is a pest of tomato (*Solanum lycopersicum* L.) and other Solanaceae, such as potato (*Solanum tuberosum* L.). The moths come to light and hide during the day. The female lays about 250 eggs on the underside of leaves or stems. The larva mines the leaf, flower, stem, or fruit of its host and goes through four instars before pupation. The whole life cycle takes 30–40 days depending on temperature conditions. There may be up to 12 generations per year (www.tutaabsoluta.com). In the Galapagos, the few specimens available were collected at light or reared as a leaf miner on potato in February, May, and November, from the arid zone to 815 m elevation on Fernandina.

DISTRIBUTION: This species is widely distributed in the Neotropical region, where it originated (Povolný, 1994). Clarke (1965) reports it from Chile, Peru, and Venezuela. It has also spread to Europe and North Africa (www.tutaabsoluta.com). In the Galapagos it is known to us from the islands of Fernandina, Isabela, and San Cristobal.

REMARKS: On Fernandina, where tomato and potato are not known to occur, this species could feed on several other Solanaceae known to occur on that island, such as members of *Acnistus*, *Exodeconus*, *Jaltomata*, *Physalis*, and *Solanum* (Lawesson *et al.*, 1987). The status of the endemic species of Solanaceae may be at risk from damages caused by *P. absoluta*.

***Scrobipalpula*** Povolný, 1964

This genus, including *Scrobipalpulopsis* Povolný, synonymized by Hodges in Lee *et al.* (2009), is mostly found in the Western Hemisphere, with one super species or species complex (*S. psilella* (Herrich-Schäffer)) in the Palaearctic region. It includes about 48 described species in the Nearctic and Neotropical regions combined (Povolný, 1994; Powell & Povolný, 2001; Lee *et al.*, 2009). The new species described below are part of the group with three paired (or simple) processes of the sacculus and valva. Nevertheless, all Neotropical species of *Scrobipalpula* sensu lato were checked to make sure that our Galapagos species was new. These include the 33 species listed by Povolný (1994) as well as 8 more described by Povolný (1987) in either *Scrobipalpula* or *Scrobipalpulopsis*, but later moved to other genera. Species of *Scrobipalpula* mostly feed as larvae on Asteraceae, but also on Chenopodiaceae, Polemoniaceae, Rosaceae, Scrophulariaceae, and Solanaceae (Powell & Povolný, 2001; Robinson *et al.*, 2007).

***Scrobipalpula densata*** (Meyrick, 1917) Figs 18, 58, 59

*Phthorimaea densata* Meyrick, 1917: 42.
*? Scrobipalpula densata* (Meyrick). – Povolný, 1967: 94, 95, fig. 84.
*Gnorimoschema densata* (Meyrick). – Meyrick, 1925: 91. – Povolný, 1989: 66, 67. – Clarke, 1969b: 148, pl. 74 figs 4–4b.
*Scrobipalpula densata* (Meyrick). – Becker, 1984: 47. – Povolný, 1990: 195, fig. 57.

MATERIAL EXAMINED: 1 ♂, 'ECU. GALAPAGOS | Sombrero Chino Ex larva | en frutos de *Cacabus* | *miercii* [sic] 6 VII 1998 | C. Causton No. 99.31', 'slide | BL 1668 $'. Deposited in CDRS.

DIAGNOSIS: A brown moth (Fig. 18) with dark brown at base, as a patch at about 1/4 from costa to middle of wing, and as a spot just before apex; also with chestnut-

brown scales; forewing length: 5.13 mm in Galapagos specimen. The wing pattern doesn't allow a determination among species of *Scrobipalpula*. The male genitalia (Fig. 58) are similar to those of a group of species including *S. ilyella* (Zeller, 1877), *S. ephoria* (Meyrick, 1917), and *S. caustonae* sp. n., but on the phallus, the long coecum penis, reaching about 44% of the whole phallus length, the curved apical point, and the short subapical point, both directed to the right, are diagnostic. Among other Galapagos gelechiids this species is most similar to *Phthorimaea absoluta* Meyrick, but it is larger by 1 mm in forewing length, and it has distinct dark brown markings.

REMARKS: This species had not been recorded previously in the Galapagos. It was known only from Peru. The single known Galapagos locality, Sombrero Chino, is a small islet north of the island of Santa Cruz.

The illustration of a female *S. densata* by Povolný (1967: 92) was actually that of a *Symmetrischema laciniosa* (Meyrick, 1931) as explained by Povolný (1989: 66, 67), and the female of *S. densata* hasn't been described.

A second, smaller specimen of Gelechiidae (forewing length: 4.56 mm) was reared from fruits of *Cacabus miersii* (Hook. f.) Wettst. (Solanaceae) by C. Causton (No. 99.32) collected on Fernandina island, two km west of Punta Espinoza (specimen in CDRS). The female genitalia (slide BL 1178) (Fig. 90) are very similar to those of *Scrobipalpula fjeldsai* Povolný (1990: 190), also illustrated more fully by Povolný (1967: 96), except for the asymmetric anterior apophyses. This, however, may be the result of a malformation although such asymmetry sometimes occurs in *Gnorimoschema* and *Euscrobipalpa* (see Povolný, 2002). The two Galapagos moths appear similar externally, although the male is larger and darker, but both are damaged and have the fringes stuck together as if the specimens have been wetted. For the time being, until more specimens become available, the female is identified as *Scrobipalpula ?densata* (Meyrick).

The host plant, also known as the Galapagos shore petunia, is endemic and distributed on most of the Galapagos islands (McMullen, 1999).

***Scrobipalpula inornata*** Landry, sp. n. Figs 19, 60, 61, 91

HOLOTYPE: ♂, 'ECU[ADOR]., GALAPAGOS | Española, Bahía | Manzanillo, 25.iv.1992 | M[ercury]V[apour]L[amp], leg[it]. B. Landry', 'HOLOTYPE | Scrobipalpula | inornata | B. Landry". Specimen in excellent condition, not dissected. Deposited in the MHNG.

PARATYPES: 25 ♂, 25 ♀ from the Galapagos Islands, Ecuador. – *Baltra*: 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 4923), arid zone, 24.i.1989, M[ercury]V[apour]L[amp] (B. Landry). – *Española*: 4 ♂ (1 dissected, slide MHNG ENTO 5359), 1 ♀ (dissected, slide MHNG ENTO 5955), same data as holotype; 2 ♂, same data except 29.iv.1992; 1 ♂, Las Tunas Trail, 100 m elev[ation]., 30.iv.1992, MVL (B. Landry). – *Pinzon*: 1 ♂ (dissected, slide MHNG ENTO 5958), 1 ♀, playa Escondida, 14 m elev., S 00° 35.928', W 90° 39.291', 27.iii.2006, u[ltra]v[iolet]l[ight] (P. Schmitz); 2 ♂, 5 ♀, plaja [sic] Escondida, 20.iv.2002, uvl (B. Landry, L. Roque). – *Plaza Sur*: 1 ♀, 14 m elev., S 00° 34.982', W 90° 09.936', 15.iv.2006, uvl (P. Schmitz). – *Rabida*: 3 ♂, 1 ♀, Tourist Trail, 3.iv.1992, MVL (B. Landry). – *Santa Cruz*: 1 ♂, C[harles]D[arwin]R[esearch]S[tation], Arid zone, 17.i.1989, MVL (B. Landry); 1 ♀, casa L. Roque-Albelo & V. Cruz, G[lobal]P[ositioning]S[ystem]: 13 m elev., S 00° 42.595', W 90° 19.196', 27.ii.2005, uvl (B. Landry); 1 ♀, E[stacion].C[ientifica].C[harles].D[arwin]., 4.iii.1992, MVL (B. Landry); 2 ♀, same data except 6.iii.1992, UVL; 1 ♀, same data except 7.iii.1992; 4 $ (one dissected, slide MHNG ENTO 5956), 4 ♀ (one dissected, slide MHNG ENTO 5957), low agriculture zone,

GPS: S 00° 42.132', W 90° 19.156', 13.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♂, CDRS base of El Barranco, GPS: S 00° 44.305', W 90° 18.105', 18.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♀, CDRS, wall of Invert[ebrate]s Lab[oratory]., GPS: elev. 11 m, S 00° 44.478', W 90° 18.132', 19.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♀, Finca Vilema, 2 km W Bella Vista, 1.iv.1992, MVL (B. Landry); 1 ♂, agriculture zone, finca C. Troya, N Bella Vista, GPS: 294 m elev., S 00° 40.756', W 90° 18.671', 9.iv.2004, uvl (B. Landry); 1 ♀, CDRS, Barranco, 20 m elev., 30.iv.2002, uvl (B.. Landry); 1 ♀, Barranco, E.C.C.D., 13.ix.1999, MVL (L. Roque); 1 ♀, (Indefatigable), xii.1968, B[ritish].M[useum]. 1969–17, Ref. No. L (R. Perry & Tj. De Vries). – *Santa Fé*: 2 ♂, Tourist trail, 28.v.1992, MVL (B. Landry). – *Seymour Norte*: 1 ♂, 1 ♀, Arid zone, 23.i.1989, MVL (B. Landry); 1 ♂, GPS: 17 m elev., S 00° 23.935', W 90° 17.369', 22.iii.2004, uvl (B. Landry, L. Roque, P. Schmitz). Deposited in BMNH, CDRS, CNC, and MHNG.

Other material examined: 28 unspread, pinned or glued specimens of both sexes collected at light at the Darwin Station, Santa Cruz Island, by J. & N. Leleup in October and November 1964 (MHNG); 2 unspread, pinned specimens from the same locality, collected on 22 and 25 February 1964 by D. Q. Cavagnaro & R. O. Schuster (CAS).

Etymology: The species name refers to the absence of markings on the forewing of the moth.

Diagnosis: Among Galapagos Gelechiidae this species is remarkable in its unmarked, uniformly coloured light beige forewings, thorax, and head. *Scrobipalpula flava* Povolný, from Argentina, has no markings on the forewing, but its colour is straw yellow, the hindwing is pure white, and the length of the forewing is two to three times that of *S. inornata*. *Scrobipalpula pallens* Povolný, from Argentina and Chile, may have individuals that are 'almost clear whitish cinereous' (Povolný, 1987: 20), but most individuals are darker grey to blackish, and the forewing length is between 4 and 6 mm. The two species also have obvious genital differences with regard to *S. inornata*.

Description: *Male* (n=26) (Fig. 19). Head with very small ocelli, scale cover appressed, with scales of posterior part of head converging medially, and scales of anterior part converging medioanteriorly; colour whitish beige with scales of posterior part slightly darker, subapically tinged with light greyish brown (SLGB). Haustellum white. Labial palpus whitish beige, laterally with some scales subapically tinged with light greyish brown at bases of palpomeres 2 and 3; palpomere 3 slightly shorter than second; palpomere 2 with furrow ventrally. Antennal scape without pecten, whitish beige, sometimes with scales SLGB; flagellomeres ringed with light beige and light greyish brown. Thorax with scales coloured as posterior part of head; postscutum with white scales laterally; postscutellum scaled light greyish brown. Foreleg coxa whitish beige, with few scales SLGB; femur mostly greyish brown, with scales subapically tinged greyish brown; tibia brown, with scales white at base and apex, subapically brown, with beige spots at base, 1/3, 2/3, and apex; tarsomeres I–IV concolorous with tibia, apically ringed whitish beige; tarsomere V brown. Midleg patterned as foreleg, but lighter, beige with fewer scales subapically tinged brown. Hindleg whitish beige, with few subapically tinged brown scales on tibia laterally, lateral tibial spines, and bases of tarsomeres. Forewing length: 3.1–3.7 mm (Holotype: 3.4 mm). Forewing beige, with scales SLGB, darker tinged toward apical 1/3 of wing and base of costa; fringe concolorous. Hindwing greyish brown with greyish beige fringe. Abdomen dark greyish brown dorsally on first two segments, paler toward apex, each segment apically with row of greyish white scales; ventrally whitish beige; sternum VIII about 2 X length of VIIth, narrower, with basal margin broadly concave, reinforced with

narrow, strongly sclerotized band; tergum VIII slightly shorter than sternum, about 1/3 broader, apically broadly rounded, without basal reinforcement.

Male genitalia (n=3) (Figs 60, 61). Uncus mediodorsally with erect, rounded mouse ear-like projections with serrated margins and separated by space shaped like normal distribution curve; in ventral aspect rounded with lateral margins slightly tapering to pair of short, rounded projections between rounded median notch. Gnathos a circular shallow bowl with strongly sclerotized margins and short, narrow arms, spinulose on circular section with spinules longer marginally. Tegumen long and narrow, 3 X longer than uncus, dorsal connection 2/3 length of tegumen, dorsally with postmedian, shallow depression; in dorsal view with lateral margins converging until 2/3, then parallel sided; pedunculi moderately wide. Valva narrow, slightly curving outward before middle, curved inward and downward subapically; slightly longer than tegumen and reaching slightly beyond uncus; apex with margin slightly concave, with short setae ventrally and dorsally; distal half with sparse setation of moderate length laterally. Median sacculus processes about half as long as valva, connected on basal half, with free distal parts slightly tapering and converging, with short, sparse setation ventrally on distal 2/3 and dorsally at apex. Lateral sacculus processes laterally compressed to thin sheets with wide base and narrow distal half, slightly shorter than median parabasal processes, apically with short apical tooth projecting dorsally and few short setae. Parabasal processes digit-like, short, about 1/3 length of median sacculus processes, directed slightly outward, with short setae dorsally. Vinculum and saccus equal in length; saccus tapering, with rounded apex. Phallus thin and long, slightly longer than whole genital capsule, upcurved gently, base only slightly enlarged, with short, narrower coecum, apically with two narrow 'cornuti' connected at base, more apical one hook-like, other boomerang-like.

*Female* (n=25): Antenna and colour as in male. Frenulum with 3 acanthae. Forewing length: 3.1–3.9 mm. Abdominal segment VII about 2 X length of preceding segment, slightly more strongly sclerotized, with apical margin straight.

Female genitalia (n=3) (Fig. 91). Papillae anales lightly sclerotized, slightly elongate, setose. Posterior apophyses thin, straight and long, reaching ostium in extended position. Anterior apophyses straight, slightly directed outward, short, about 1/5 length of posterior apophyses. Segment VIII ventrally well sclerotized except along straight apical margin, without microsculpture, with spiculose, triangular sections laterally from bases of anterior apophyses to apical margin, along apical margin, and ventrally toward antrum, with narrow, shallow longitudinal furrow ventrally; segment VIII dorsally with membranous, spiculose median band longitudinally flanked by narrow, sclerotized bands curving laterally with narrow laterodorsal ends set with short setae, not connected dorsally. Ductus bursae long, with slightly enlarging posterior half well sclerotized and spiculose, median 1/4 membranous, and anterior third well sclerotized; ductus seminalis inserted next to connection between ductus and corpus bursae. Corpus bursae pear shaped, slightly longer than ductus bursae; signum a pointed hook on left side at posterior 1/4.

BIOLOGY: The host plant is unknown. The moths are attracted to light and have been collected from January until May, and from September until December, at low elevations, from sea level to 294 m above sea level.

DISTRIBUTION: Galapagos islands of Baltra, Española, Pinzon, Plaza Sur, Rabida, Santa Cruz, Santa Fe, and Seymour Norte.

REMARKS: The distribution of this presumably endemic species is curious. Based on available material it is absent from the oldest island, San Cristobal, and from the youngest islands, Isabela and Fernandina.

***Scrobipalpula equatoriella*** Landry, sp. n. Figs 20, 21, 62, 63, 92

HOLOTYPE: ♂, 'ECU[ADOR]., GALAPAGOS | Santa Crúz, E[stacion].C[ientifica]. C[harles].D[arwin]. | 7.iii.1992, U[ltra]V[iolet]L[light] | leg[it]. B. Landry', 'HOLOTYPE | Scrobipalpula | equatoriella | B. Landry'. Specimen in excellent condition, not dissected. Deposited in the MHNG.

PARATYPES: 4 ♂, 15 ♀ from the Galapagos Islands, Ecuador. – *Baltra*: 2 ♀ (one without abdomen), arid zone, 24.i.1989, M[ercury]V[apour]L[amp] (B. Landry). – *Santa Cruz*: 1 ♂, casa L. Roque-Albelo & V. Cruz, G[lobal]P[ositioning]S[ystem]: 137 m elev[ation]., S 00° 42.595', W 90° 19.196', 20.ii.2005, u[ltra]v[iolet]l[light] (B. Landry); 1 ♂ (dissected, slide MHNG ENTO 5960), 4 ♀ (one dissected, slide MHNG ENTO 5959), same data as holotype; 5 ♀ (one dissected, slide MHNG ENTO 5961), wall of Invert[ebrate]s. Lab[oratory]., GPS: elev. 11 m, S 00° 44.478', W 90° 18.132', 19.iii.2004, uvl (B. Landry, P. Schmitz); 4 ♀, same data except 6.iv.2004; 2 ♂ (one dissected, slide B.M. No. 29741), xii.1968, B[ritish].M[useum]. 1969–17, Ref. No. L. 52 (R. Perry & Tj. De Vries).
Deposited in the BMNH, CDRS, CNC, and MHNG.

ETYMOLOGY: The species name refers to the fact that this species has been collected in Ecuador and on the equatorial line.

DIAGNOSIS: Among the Gelechiidae of the Galapagos this smallest of all species (2.5–2.9 mm forewing length) is most similar to *Agnippe omphalopa* (Meyrick) and *Ephysteris sporobolella* (see under Diagnosis of *A. omphalopa*). Among *Scrobipalpula* species this one is most similar in male genitalia to *S. dispar* (Povolný, 1990), **comb. n.**, described from Arequipa, Peru, on the basis of the spatulate gnathos, the long and thin phallus with a serrated flange subterminally, the elongate saccus, and especially, the simple median sacculus process. However, in *S. equatoriella* the median sacculus process is broader and shorter, as are the paired lateral sacculus processes, the apical margin of the uncus has additional lateral projections, and the valva has the curved distal section longer and thinner.

DESCRIPTION: *Male* (n=5) (Fig. 20). Head with ocelli, dorsally and anterad from antennae with lateral scales projected medially and slightly upward, forming low crest, appressed on fronto-clypeus; mostly cream, but laterally on fronto-clypeus with scales subapically tinged dark brown and dorsally with fewer scales subapically tinged lighter brown. Haustellum white. Labial palpus with palpomere 1 white, tinged with grey brown, palpomeres 2–3 ringed dark brown and white laterally, medially paler, with rings less distinct; palpomere 3 slightly shorter than 2nd; palpomere 2 with indistinct furrow ventrally. Antennal scape without pecten, mostly dark brown, with white base of some scales showing; flagellomeres mostly dark brown, with every second ring of scales showing slightly paler base. Thorax with mesothorax mostly cream, tinged with ochre laterally; tegula basally dark brown, apically ochre; postscutum with whitish-grey scales laterally; postscutellum greyish brown. Foreleg coxa mostly white at base, posteriorly mostly dark brown, with scales' base and apex white; femur as posterior

end of coxa; tibia dark brown with cream rings most prominent postmedially and apically; tarsomeres dark brown, with apical cream rings on I–IV. Midleg coxa and femur cream, with few brown scales; tibia dark brown with extensive cream rings before and after middle, and apically; tarsomeres as on foreleg. Hindleg coxa and femur as on foreleg; tibia mostly cream, including dorsal hair pencil, with dark brown at base, submedially, and subapically; tarsomere I as tibia, II–V as on midleg. Forewing length: 2.5–2.7 mm (Holotype: 2.7 mm). Forewing cream tinged with ochre below fold from base to 3/5; above fold mostly greyish brown, with more or less distinct diagonal cream bands at 1/5, 2/5, and 4/5, with dark brown dashes in fold at 2/5 and along midline at 3/5 and subapically (often less distinct), also with light ochre to brown at termen, as spot submedially, below costa as broken line, and in fold; fringe mottled with scales greyish brown subapically and white at base and apex. Hindwing blackish brown, becoming paler greyish brown on distal 1/3; costa with long, thin scales on whole length; fringe greyish brown on costa, paler greyish cream elsewhere. Abdomen dorsally dark greyish brown on first 2–3 segments, subsequently paler to dirty white on two distal segments; ventrally whitish cream along middle, greyish brown laterally; sternum VIII about 2 X length of VIIth but equal in width, with basal margin broadly concave, reinforced by narrow, strongly sclerotized band, with apical margin slightly rounded; tergum VIII slightly shorter than sternum, about 1/3 broader, basal and apical margins straight.

Male genitalia (n=2) (Figs 62, 63). Uncus squarrish, dorsoventrally flattened, dorsal surface flat, without ornamentation, apical margin with short lateral extensions and broadly rounded medially. Gnathos spatulate, long, distal section less strongly sclerotized, with distal margin undulated. Tegumen long and moderately narrow, 4 X length of uncus, dorsal connection almost 2/3 length of tegumen, dorsally with broad and shallow postmedian depression; in dorsal view with lateral margins slightly rounded postbasally, constricted subapically; pedunculi moderately narrow. Valva narrow and long, slightly more than 1/10 shorter than tegumen + uncus, reaching tip of uncus; slightly curved downward near middle; distal half with short, sparse setation laterally and ventrally; distal 1/5 slightly dilated, curved inward at about half right angle; apex sharply pointed. Median sacculus process simple, reaching 1/3 length of valva, apically rounded, with tiny setae on two longitudinal rows ventrally and along apical margin. Lateral saccular processes moderately wide at base, tapering, reaching apex of median process, laterally compressed toward dorsal margin, apex shortly pointed, directed upward, with 4–5 tiny setae before apex dorsally. Parabasal processes digit-like, about half as long as lateral sacculus processes, with short setae mostly at rounded apex. Vinculum short; saccus narrow, slightly shorter than vinculum + median sacculus process, with apex narrowly rounded. Phallus thin and long, slightly shorter than whole genital capsule, upcurved gently, with base slightly enlarged, with lateral flange on left side serrated from 3/4 to just before downcurved apical 1/10; apex without distinct cornutus.

*Female* (n=15) (Fig. 21): Antenna slightly thinner than male's. Frenulum with 3 acanthae. Forewing length: 2.6–2.9 mm; forewing colour slightly different than male's in more ochre sector below fold; hindwing uniformly greyish brown. Abdomen segment VII slightly more than 2 X length of VIth, with apical margins slightly concave.

Female genitalia (n=2) (Fig. 92). Papillae anales short, lightly sclerotized, setose. Posterior apophyses thin, straight and long, reaching ostium in extended position. Anterior apophyses straight, directed outward slightly, about 1/4 length of posterior apophyses and slightly thicker. Segment VIII ventrally lightly sclerotized, medially with wide section (2/5 of whole width) slightly projected ventrally as elongate triangle, covered with short spines; segment VIII dorsally with wide (3/5 of whole width) median section membranous, spinulose, with elongate, narrow pockets laterally at base and reaching 2/3 length of segment, covered with comb-like microsculpture of circles with thick margins, laterally with wider sclerotized bands without microsculpture but spinulose, narrowly prolonged subdorsally at apex and setose along apical margin. Ductus bursae long, posterior 3/5 strongly sclerotized, about 1/4 width of segment VIII, posterior 1/7 widely opening; anterior 2/5 membranous, slightly narrower; inception of ductus seminalis at 6/7 on ductus bursae. Corpus bursae tear shaped, about 1.4 length of ductus bursae; signum a thin pointed hook on left side at posterior 1/4.

BIOLOGY: The host plant is unknown. The moths are attracted to light and have been collected from December until April, at low elevations mostly, from sea level to 137 m above sea level.

DISTRIBUTION: Galapagos islands of Baltra and Santa Cruz.

REMARKS: The sexual dimorphism in forewing, slightly, and especially hindwing colour is also found, for example, in *Scrobipalpula patagonica* Povolný. However, in this species the darker scaling on the hindwing is in a band along the costa and in the anal sector at base (see Povolný 1987: 85; 1994: 21).

***Scrobipalpula caustonae*** Landry, sp. n. Figs 22, 64, 65

HOLOTYPE: ♂, 'ECU[ADOR]., GALAPAGOS | Floreana, Punta | Cormoran, 21.iv.1992 | M[ercury]V[apour]L[ight] | leg[it]. B. Landry', 'HOLOTYPE | Scrobipalpula | caustonae | B. Landry'. Specimen in good condition, not dissected. Deposited in the MHNG.

PARATYPES: 3 ♂ (2 dissected, slides MHNG ENTO 5360 and 5972), with same data as holotype. Deposited in the CDRS and MHNG.

ETYMOLOGY: This species honours Charlotte Causton, former head of Charles Darwin Station's Department of Invertebrates, who spent great efforts to plan, implement, and monitor the introduction of *Rodolia cardinalis* (Mulsant) (Coccinellidae) to control *Icerya purchasi* (Maskell) (Margarodidae) in the Galapagos, thus probably saving a few species of moths from extinction (Roque-Albelo, 2003).

DIAGNOSIS: This species is the only gelechiid in the Galapagos with white hindwings. The forewing pattern and colour are also unique among Galapagos gelechiids. It is close to *S. densata* (Meyrick, 1917), described from Peru, but also occurring in the Galapagos (see below), in several characters of the male genitalia such as the shape of the uncus, gnathos, valvae, saccular and parabasal processes, and phallus. It differs especially clearly in the shape of the phallus which has a shorter coecum penis and a larger subapical projection.

DESCRIPTION: *Male* (n=4) (Fig. 22). Head with ocelli, scale cover seemingly appressed (rubbed in available specimens), with lateral scales of posterior part of head

converging medially; colour apparently mainly white with small lateral and larger posterior scales apically or subapically brown. Haustellum and maxillary palpus white. Labial palpus mostly pale orange brown, with white dorsally and also laterally at tip of palpomere 2 and base and tip of palpomere 3; second palpomere ventrally with scales projecting at 45°, but not longer or forming furrow; palpomere 3 slightly shorter than 2nd. Antennal scape orange brown with apical white ring; flagellum beige with greyish-brown spot laterally and alternatingly on first few flagellomeres, with complete greyish-brown band in alternation on subsequent flagellomeres. Thorax white with orange brown to dark brown at apex of some scales; postscutellum white, shining. Foreleg coxa and femur white speckled with brown; tibia mostly brown with white at base, postmedially, and apically; tarsomeres white with brown postmedially on 1st and basally on 2nd to last. Midleg as foreleg but with more extensive white scaling, especially on femur. Hindleg as midleg, with brown markings slightly paler, orange tinged. Forewing length: 3.5–4.0 mm (Holotype: 4.0 mm). Base of forewing costa underneath with pencil of thin scales extending to about 1/5 wing length. Forewing colour creamy white with diffuse pattern of brown, mostly tinged orange lightly, with darker brown patches sub- and postmedially along midline; fringe light greyish brown. Hindwing white with light greyish-brown fringe. Abdomen dorsally white with stiffened and pointed, yellowish cream scales on terga I–III, but less modified on tergum 1; ventrally white; sternum VIII as narrow as preceding sternum, with straight basal margin and evenly convex apical margin; tergum VIII about 2/3 width and 1.5 length of sternum, broadly concave at base and roundly convex apically.

Male genitalia (n=2) (Figs 64, 65). Uncus slightly convex, short, with parallel lateral margins, rounded angles, and narrow, V-shaped cleft medially. Gnathos an upcurved plate with basal and lateral margins concave, with short arms, apically forming three short projections of equal length, one median and two lateral, rounded. Tegumen about 6 X length of uncus, dorsal connection half length of tegumen, laterally constricted subapically, pedunculi narrow. Valva slightly bent downward beyond middle, subapically enlarged, triangular, with rounded ventral point and apex; slightly shorter than tegumen and reaching before apex of uncus; with setation laterally on distal half, more sparse and shorter medially. Saccular processes stout and divergent, apically with short point directed laterally. Parabasal processes narrow and short, reaching slightly beyond saccular processes, apex slightly curved medially and with short setae. Vinculum very narrow. Saccus rounded, short, not reaching beyond margins of tegumen pedunculi. Phallus narrow, strongly sclerotized, straight but lateral margins slightly sinuate, about 2/3 length of whole genital capsule, with coecum penis distinct, narrow, at 45° from shaft, almost 1/3 length of whole phallus, apically forked with dorsal branch shorter and thicker than ventral one, latter pointed, slightly up - curved and directed to left.

*Female*: Unknown.

BIOLOGY: The host plant is unknown. The available specimens were collected at light near the sea shore.

DISTRIBUTION: Galapagos island of Floreana.

REMARKS: This species is attributed to *Scrobipalpula* because it is close to *S. densata* (Meyrick, 1917) (see Diagnosis). All known species of Neotropical

Gnorimoschemini and several Nearctic species were checked to make sure that this species was new.

***Symmetrischema*** Povolný, 1967

The genus, including subgenera *Primischema* Povolný and *Symmetrischemulum* Povolný, includes 46 species in the Neotropical region (Povolný, 1994) and 7 in the Nearctic region (Lee *et al*., 2009), with three known from both regions. The type locality mentioned for *S. capsica* (Bradley & Povolný, 1965) as England by Lee *et al*. (2009) is wrong as the species was described from the Lesser Antilles.

***Symmetrischema escondidella*** Landry, sp. n. Figs 23–26, 66, 67, 93

HOLOTYPE: ♂, 'ECU[ADOR], Galápagos, Santa Cruz | E[stacion]C[ientifica] C[harles]D[arwin], El Barranco | S 00° 44.291', W 90° 18.107' | 22 m elev[ation].,u[ltra]v[iolet] l[light], 23.iii.2006 | leg[it]. P. Schmitz', 'HOLOTYPE | Symmetrischema | escondidella | B. Landry'. Specimen in good condition, with notch on right forewing apex, with right hindwing slightly out of place, not dissected. Deposited in the MHNG.

PARATYPES: 5 ♂, 6 ♀ from the Galapagos Islands, Ecuador. – *Floreana*: 1 ♀ (dissected, slide MHNG ENTO 5975), close to Loberia, GPS: elev[ation]. 6 m, S 01° 17.002', W 90° 29.460', 11.iv.2004, u[ltra]v[iolet]l[light] (P. Schmitz). – *Pinzon*: 3 ♂ (one dissected, slide MHNG ENTO 5974), 2 ♀, Playa Escondida, S 00° 35.928', W 90° 39.291', 14 m elev., 27.iii.2006, uvl (P. Schmitz); 1 ♂, [no specific locality], S 00° 36.216', W 90° 40.033', 280 m elev., 28.iii.2006, uvl (P. Schmitz); 1 ♂ (dissected, slide MHNG ENTO 5976), 1 ♀, plaja [sic] Escondida, 20.iv.2002, uvl (B. Landry, L. Roque). – *Plaza Sur*: 2 ♀ (one dissected, slide MHNG ENTO 5973), S 00° 34.980', W 90° 09.990', 18 m elev., 14.iv.2006, uvl (P. Schmitz). Deposited in the BMNH, CDRS, and MHNG.

ETYMOLOGY: The name derives from one of the collecting localities, Playa Escondida on Pinzon Island, which means "hidden beach" in Spanish. The species also remained 'hidden' from us despite extensive collecting efforts before it was first found in 2002.

DIAGNOSIS: The conspicuous black scales found on the male's hindwing on the basal half (Fig. 23) are unique among the Gelechiidae of the archipelago and rare in Lepidoptera altogether. This character is found also in *Symmetrischema disciferum* Povolný, 1989 and in *Scrobipalpula patagonica* Povolný (see Povolný (1994: 21)), but in the first species the black scales cover the whole basal half of the wing and in the second they are found only along the costa's basal 3/4 and in the anal sector. In male genitalia our species differs from other *Symmetrischema* species by a combination of characters such as the narrow valva with a short triangular point submedially, the wide paired saccular processes with a more elongate dorsal projection, and the very tiny parabasal processes. This general shape of the male genitalia is found also in *S. lectuliferum* (Meyrick), described from Texas, USA, and illustrated by Povolný (1967: 57), but in this species the valvae are thicker, especially medially, and the phallus is longer, thinner, and mostly serrated on one side.

DESCRIPTION: *Male* (n=5) (Figs 23, 25, 26). Head with ocelli, scale cover appressed, with scales of posterior part of head converging medially and scales of anterior part converging medioanteriorly; colour of scales dirty white at base, dark to light greyish brown subapically, and pure white at tip. Haustellum white. Maxillary palpus coloured as head, with scales subapically dark greyish brown. Labial palpus

curved upward, not quite reaching top of head; segment I white; segment II mostly coloured as head, but white dorsally, with ventral scales forming median furrow; segment III coloured as 2nd, but with faint paler rings medially and subapically with scales subapically pale brown. Antennal scape without pecten, mostly black with scales dirty white at base and tip, with creamy white apical ring; flagellum at base with alternating rings of black and beige, distally with 5 series of 3 black rings followed by 1 beige ring, followed at tip by 1 black and 1 beige rings. Thorax mostly with scales coloured as on head, but darker anteriorly and with chestnut brown in middle of tegulae; postscutellum grey, shining. Foreleg coxa with scales tricoloured as on head, with black median area of scales small; femur as coxa, but black on scales more prominent; tibia mostly black, with white bands submedially, postmedially, and apically; tarsomere I black, with beige at base and tip; tarsomeres II and V black with beige at tip; tarsomeres II and III black. Midleg coxa beige; femur as on foreleg but more prominently beige, especially at base; tibia as on foreleg, but paler sections of scales more prominent, with white bands postmedially and apically; tarsomeres as on foreleg. Hindleg coxa beige; femur mostly beige, with some greyish brown; tibia as on midleg, but with base mostly beige; tarsomere I black with three beige bands at base, middle, and apex; tarsomeres II–V black at base and beige at tip. Forewing length: 3.57–4.05 mm (Holotype: 3.95 mm). Forewing upper side appearing dark brown, with most scales tricoloured except black ones forming diagonal patch on costa to midline at 1/4, three dashes increasing in length just above midline before and after middle and at 4/5, and 3–4 smaller spots at and near base; also with chestnut-brown scaling forming 4 longitudinal lines above midline at 1/3 and between 1/2 and 4/5, patches before and after middle along midline, patch along fold at 1/3, as longitudinal line above dorsum between 1/4 and 3/5, and following faint transverse pale line at 2/3; fringe pale greyish brown; underside of wing (Fig. 26) with black scaling between 1/5 and 2/3. Hindwing greyish brown with concolorous fringe and black scaling from slightly beyond base to 2/3 along costa and to 1/2 along dorsum except along medial fold and in oval area at base of anal sector; costa with thin beige and black scales slightly longer than hair-like scales of fringe from base to 2/5; underside also with black scaling mostly along costa from 1/5 to 3/5 and in cubital sector. Abdomen greyish brown with apical row of dirty white scales on most segments except first two and above genitalia; on each side of genitalia with short tuft of thin beige scales projecting upward at 45°; laterally and ventrally dirty white with row of dark brown spots on each side of midline ventrally, with greyish-brown scales in middle of penultimate segment and under genitalia; sternum VIII almost 2 X length of sternum VII, with basal margin shallowly concave and apical margin broadly rounded; tergum VIII about as long as sternum, with basal margin reinforced by thin sclerotized band, broadly concave, with apical margin straight.

Male genitalia (n=2) (Figs 66, 67) Uncus a rather narrow band, 1/6 length of tegumen, with basal and apical margins rounded in parallel, well separated from more lightly sclerotized tegumen. Circumanal membrane strongly developed, forming broad V, with ventral branches of V strongly sclerotized, abundantly scobinated. Gnathos a short, narrow, and straight point attached medially on centrally fused thicker arms. Tegumen dorsally flat, dorsal connection 1/2 total length but with basal 1/4 more strongly sclerotized, subapically constricted and then enlarging slightly. Valva narrow,

subapically enlarged slightly, then narrowing, apically narrowly rounded; reaching middle of gnathos; evenly curved downward and laterally; with short triangular point medially at middle; with short to long setae on distal half mostly ventrally. Paired saccular processes wide, closely approximate ventrally, with short, glabrous ventral projection separated by broadly rounded concavity to shortly setose, digitate projection reaching slightly beyond middle of valva. Paired parabasal processes very tiny, narrow, with one apical seta. Unpaired saccular process short, not quite reaching tips of ventral projections of paired saccular processes, apically blunt. Vinculum short, with lightly sclerotized, rounded dorsal margins and strongly sclerotized reinforced ventral margins; saccus moderately long and narrow, slightly upturned and blunt at proximal end. Phallus narrow, slightly longer than valva, slightly curved to right, with distinct, slightly enlarged and rounded coecum, apically with short, dorsal, lightly sclerotized, digit-like projection, ventrally with apical margin shallowly concave medially with rounded sides.

*Female* (n=6) (Fig. 24): Antenna and colour as in male. Frenulum with 3 acanthae. Forewing length: 3.62–4.52 mm. Both fore- and hindwings without black scaling or long scales at base of hindwing costa as found in male. Abdomen segment VII twice as long as preceeding, narrower and narrowing, with apical margins slightly concave.

Female genitalia (n=2) (Fig. 93). Papillae anales subtriangular, apically rounded, lightly sclerotized, moderately setose. Posterior apophyses thin, straight, and long, 3.2 X length of anal papillae, reaching ostium in full extension. Anterior apophyses thin, straight, about 2/5 length of posterior ones. Membrane at midpoint between segment VIII and papillae anales with large, rounded dorsal extension 1/3 longer and wider than distance between posterior apophyses at that point. Segment VIII with strongly sclerotized, straight anterior margin; with intersegmental membrane lightly sclerotized along anterior margin medially and lateroposteriorly, with spicules on strictly membranous median section distally; ostium in circular membranous area medially adjacent to anterior margin of segment; laterally with sclerotized areas extending posteriorly, narrowing, not completely enclosing membranous area around ostium, forming pair of medially opened, heavily spinulate cavities near middle of segment, ending laterally in bands; membrane between lateral sclerotized areas less densely spinulate. Ductus bursae with short sclerotized section posteriorly, with dorsal inception of ductus seminalis, subsequent section about as long as segment VIII, posteriorly straight, anteriorly curved with narrow sclerotized triangle adjacent to small, strongly sclerotized patch. Corpus bursae narrow, curved, gradually enlarging to anterior section about twice as wide, distally rounded.

Biology: The host plant is unknown. The moths come to light and specimens have been collected near the sea shore, but also up to 280 m, in March and April.

Distribution: Galapagos islands of Floreana, Pinzon, and Plaza Sur.

Remarks: The keys provided by Povolný (1994) for the Neotropical genera place this species in *Symmetrischema* s. str. for the males while it leads to a dead end for the females. Our new species can be quite confidently associated with *Symmetrischema* because in male genitalia it bears an unpaired process arising from the centre

of the sacculus wall ventrally, which is the first character mentioned in the original description (Povolný, 1967) to 'characterize' the genus. The second 'specific character' mentioned by Povolný (1967) is the apically enlarged valvae, but this is 'probably secondarily narrowed' in some species, such as *S. escondidella*. The gnathos of *Symmetrischema*, as mentioned by Povolný (1967) is 'either reduced to form a mere chitinous half-ring... or transformed to a short triangular beak,' the latter being the condition observed in our new species. Finally, as found in our species, the circumanal membrane (scaphium and subscaphium) is often strongly developed, often reaching beyond the uncus. In female genitalia the only character mentioned in the original description as being 'characteristic' for the genus is the tendency toward a reduction of the signum bursae, which is completely absent in our new species. All North American and Neotropical species of *Symmetrischema* were checked to determine that our species was new.

**Litini**

***Agnippe*** Chambers, 1872

Genus *Agnippe*, including *Evippe* Chambers, just synonymized by Lee & Brown (2008) includes 23 species occurring in North America, Europe, and Asia according to Lee & Brown (2008). However, these authors did not record *A. ompha - lopa* (Meyrick) and four other Neotropical species mentioned by Becker (1984), although they mentioned that *Tholerostola* Meyrick, the genus in which and for which *omphalopa* was described, is a synonym of *Agnippe*.

The description of *Agnippe* provided by Lee & Brown (2008) differs significantly in several characters when *A. omphalopa* is taken into consideration.

Recorded host plants for *Agnippe* species are in the Fabaceae, Fagaceae, and Rosaceae (Lee & Brown, 2008). Thus, our host plant record for *A. omphalopa* is not surprising.

***Agnippe omphalopa*** (Meyrick, 1917), comb. n. Figs 27, 28, 68, 69, 94

*Tholerostola omphalopa* Meyrick, 1917: 40, 41. – Meyrick, 1925: 88. – Clarke, 1969b: 476, pl. 238 figs 1–1d.
*Evippe omphalopa* (Meyrick). – Becker, 1984: 45.

MATERIAL EXAMINED: 11 ♂, 11 ♀. Male lectotype (dissected, slide 6244, Clarke), described from "Ecuador, Duran, low country" (BMNH). – *Isabela, Sierra Negra*: Puerto Villamil; 1 km W Puerto Villamil; 2 km W Puerto Villamil; 8.5 km N Puerto Villamil. – *Pinta*: Plaja Ibbeston [sic]; ±15 m elev.; ±50 m elev. – *Pinzon*: ±25 m elev. Deposited in the BMNH, CDRS, CNC, and MHNG.

DIAGNOSIS: A tiny moth (forewing length: 2.7–3.2 mm) that resembles perhaps only two other similarly small gelechiid species of Galapagos: 1- *Scrobipalpula equatoriella* sp. n. has pale off-white scaling on the head, thorax, genitalia, and dorsum of forewing and the male hindwing is deep dark brown, especially at base; and 2- *Ephysteris sporobolella* sp. n., which often has the base of the forewing dorsum paler than the adjacent, costal part of the wing, which is usually contrastingly darker, and the base of the forewing subcostal vein has an overlay of orange-ochre scales. Among the other species of *Agnippe*, *A. omphalopa* is one of two described from the Neotropical region that do not have the dorsum of the forewing mostly white and contrasting with

dark brown or black. The other species, *A. plumata* (Meyrick, 1917) is darker, blackish brown with some bronze, shining scales (but whole type series severely rubbed) (see Clarke, 1969b: 89, pl. 44), compared to *A. omphalopa*, its costal part of valva is shorter, apically narrowing and sparsely setose, and its phallus apically shows a narrow, sclerotized band curved onto itself.

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=11) (Fig. 27): Head without ocelli. Scape without pecten. Forewing length: 2.7–3.1 mm. Tergum VIII wider and more strongly sclerotized than tergum VII, with apical margin broadly produced and rounded, without associated hair pencil. Sternum VIII at base about half as wide as sternum VII and altogether almost 3 X as long; gradually tapering from base until middle then more strongly so until short apical widening; apically blunt, with tiny median depression.

Male genitalia (n=3) (Figs 68, 69). Uncus basally wider, gently tapering to blunt apex, latter slightly down curved. Gnathos with dorsal, spatulate part slightly wider and longer than uncus, very thin, down curved; ventral part about as wide and as long as uncus, straight except for simple, short, rounded and flattened tip upturned at right angle. Tegumen about 1/5 longer than uncus, with pedunculi moderately wide, with dorsal sclerotized bridge 3/10 of whole length. Costal part of valva with wide base, narrow in middle, with apex enlarged and densely setose medially; saccular part of valva asymmetrical: on right side forming tiny, curved 'claw,' on left side forming digitate peduncle projecting upward to costal margin of costal part of valva, then with long, laterally flattened 'sword' directed ventrally, reaching apex and ventral margin of costal part of valva, without setae, apically pointed and slightly turned medially. Vinculum's posterior margin slightly asymmetrical, rounded, with few, tiny setae laterally more apically situated on right side; saccus asymmetrical, with left branch about 1/5 longer than right branch, lightly sclerotized between branches apically. Phallus elongate, index finger-like, with longitudinal, strongly sclerotized, narrow bar along ventral edge from 2/5 till before apex; vesica without cornuti.

*Female* (n=11) (Fig. 28): Antenna slightly thinner than male's; colour and forewing pattern as in male; frenulum with 3 acanthae; forewing length: 2.7–3.2 mm. Tergum VII unmodified. Apical margin of sternum VII with median concavity nearly reaching middle of sternum.

Female genitalia (n=2) (Fig. 94). Papillae anales lightly sclerotized, with short to long setae, especially along basal and dorsal margins and apically. Posterior apophyses thin, straight, about 2 X as long as anterior apophyses, reaching middle of antrum in full extension. Anterior apophyses more strongly sclerotized than posterior, reaching posterior margin of segment VI. Antrum situated medially, funnel shaped, about half as long as segment VII at lateral, longest point. Ductus bursae narrower and half as long as antrum. Corpus bursae with slightly elongate, main section containing broad, flattened, convex, and irregularly rounded signum with short median crest, also with band of spinules before posterior end; accessory bursa longer, narrower, curving anteriorly to surround anterior end of main section, with spinules along most of posterior half.

BIOLOGY: The two specimens from Pinzon Island were reared from immatures collected in leaflets of *Prosopis juliflora* (Sw.) DC. (Fabaceae). This small tree or shrub

is found on several islands of the archipelago and considered native (Lawesson *et al.*, 1987). It is an inhabitant of the arid lowlands and although it originated from South America, it is now widespread in tropical regions around the world (McMullen, 1999). Moths come to light and were collected in March and April in the arid zone of the Galapagos.

DISTRIBUTION: Described from continental Ecuador, and here mentioned from the Galapagos archipelago (Isabela, Pinta, and Pinzon) for the first time. It is undoubtedly more widespread in the archipelago and elsewhere.

REMARKS: The type series of *A. omphalopa* consisted of nine specimens (Meyrick, 1917). Clarke (1969b) designated a lectotype, recorded seven other syntypes, and gave illustrations of the habitus, head, wing venation, and male genitalia. The Galapagos specimens were identified by comparison with the lectotype.

### Anacampsini

***Anacampsis*** Curtis, 1827

This is a relatively large genus with 34 species recorded from the Neotropics (Becker, 1984), 23 from the Nearctic Region (Lee *et al.*, 2009), 9 in Europe (Karsholt & Riedl, 1996), 2 in South Africa (Vári *et al.*, 2002), and 2 in India and Sri Lanka (Meyrick, 1925). Host plants are in a wide variety of families such as Betulaceae, Rosaceae, and Salicaceae in the Holarctic region and Anacardiaceae, Combretaceae, Euphorbiaceae, Fabaceae, and Malvaceae in the Neotropical region (Robinson *et al.*, 2007).

***Anacampsis primigenia*** Meyrick, 1918 Figs 29–32, 70–72, 95

*Anacampsis primigenia* Meyrick, 1918: 141. – Clarke, 1969a: 238, pl. 118 figs 2–2a. – Becker, 1984: 48.

MATERIAL EXAMINED: 44 ♂, 61 ♀, 18 of unrecorded sex. Male lectotype, described from 'Huigra, 4,500 feet, Ecuador, Parish.6.14' (BMNH). – *Española*: bahia Manzanillo; Las Tunas Trail, 100 m elev. – *Fernandina*: SW side, 815 m elev., S 00° 21.270', W 091° 35.341'; SW side, crater rim, 1341 m elev., S 00° 21.910', W 091° 34.034'; N side, 1300 m elev. – *Floreana*: Las Cuevas; close to Loberia, 6 m elev., S 01° 17.002', W 90° 29.460'; Finca Las Palmas, 300 m elev.; scalesias near Cerro Pajas, 329 m elev., S 01° 17.743', W 90° 27.111'; Cerro del Asilo, 366 m elev., S 01° 18.931', W 90° 27.232'. – *Genovesa*: Bahía Darwin. – *Isabela, Alcedo*: [West side], bahia Urvina ex larva en Croton scouleri; lado NE, 200 m elev., camp arida alta; NE slope, 292 m elev., S 00° 23.829' W 91° 01.957'; lado NE, 400 m elev., camp pega-pega; lado NE, 700 m elev., camp guayabillos; 900 m elev.; lado NE, 1100 m elev., cumbre, caseta Cayot. – *Isabela, Darwin*: Tagus Cove; [W slope] 300 m elev.; [W slope] 630 m elev. – *Isabela, Sierra Negra*: 1 km W Puerto Villamil; 2 km W Puerto Villamil; 8.5 km N Puerto Villamil; 11 km N Puerto Villamil; ±15 km N Puerto Villamil; 3 km N Santo Tomas, Agriculture Zone. – *Marchena*: [no specific locality]; Playa Negra. – *Pinta*: Cabo Ibbetson, N 00° 32.819', W 90° 44.229'; 200 m elev.; 400 m elev.; 421 m elev., N 00° 34.591', W 90° 45.137'. – *Pinzon*: Playa Escondida, S 00° 35.928', W 90° 39.291'. – *Rabida*: tourist trail. – *San Cristobal*: Puerto Baquerizo; 2 km SW Puerto Baquerizo; 4 km SE Puerto Baquerizo; base of Cerro Pelado; mina de ripio, en Croton scouleri. – *Santa Cruz*: littoral zone, Tortuga Bay; bahia Conway; Charles Darwin Research Station; Barranco, arid zone; transition zone, house of L. Roque, 137 m elev., S 00° 42.595' W 90° 19.196'; low agriculture zone, S 00° 42.132', W 90° 19.156'; 2 km W Bella Vista; finca Steve Devine; finca Vilema, 2 km W Bella Vista; NNW Bella Vista, 225 m elev., S 00° 41.293', W 90° 19.665'; agriculture zone, finca C. Troya, N Bella Vista, 294 m elev., S 00° 40.756', W 90° 18.671'; Tortuga Reserve, W Santa Rosa; Los Gemelos; pampa zone, Media

Luna. – *Santa Fe*: tourist trail. – *Santiago*: Bahia Espumilla; La Bomba, 6 m elev., S 00° 11.151' W 90° 42.052'; N side, 437 m elev., S 00° 13.316' W 90° 43.808'; 200 m elev.; Aguacate, 520 m elev.; Central, 700 m elev.; Jaboncillo, ±850 m elev. – *Seymour Norte*: arid zone; [no specific locality]. – *Sombrero Chino*: ex larva en frutos de Cacabus miercii [sic]. – *Wolf*: N 01°23.380', W 91° 49.201'. Deposited in the BMNH, CDRS, CNC, and MHNG.

Diagnosis: Many species of *Anacampsis* have a look similar to that of *A. primigenia*. Our species is perhaps more similar to *A. capyrodes* Meyrick, especially in size, although this species has darker, chocolate-brown fore- and hindwings and a more uniformly coloured forewing with a very faint, paler postmedian line. Given its rather large size and dark brown wings this species is unlike any other in the Galapagos.

Additions to original Description: *Male* (n=44) (Figs 29, 31): Scape without pecten. Ocelli present. Forewing length: 4.5–6.4 mm. Forewing pattern sometimes with more apparent dark brown markings as spots (Fig. 31), longitudinal lines (Fig. 32), or with distinctly paler costal area (Fig. 30). Hindwing without hair pencil on costa. Tibia with dense scale tuft dorsally. Segment VII unmodified.

Male genitalia (n=5) (Figs 70–72). Uncus strong, slightly down curved, slightly narrowing toward apex, with short point apically, with abundant, long setation. Gnathos absent. Tegumen strong, slightly convex, with wide arms at almost right angle from dorsal part, about 2/3 length of dorsal part, with short, thin scales dorsally on distal 2/3. Valva narrow, laterally compressed, slightly downcurved subbasally, with basal 2/5 wider, apical 1/10 slightly upturned, with moderate setation, medially at base with some setal bases slightly projecting, apically narrowing and rounded. Vinculum a pair of narrow lateral rods about half as long as valvae, with membrane in between dorsally forming pair of short rounded projections adorned with abundant setation of variable length; saccus short, about 1/3 length of lateral rods, an elongate V with lateral margins more strongly sclerotized and slightly concave, with anterior end blunt to narrowly rounded. Membrane all around phallus with abundant short setation. Phallus short, about half as long as valva, with basal half enlarged slightly, and apical half a narrow tube; in lateral view with ventral margin slightly convex, in middle with short hook projecting anteriorly, dorsal margin dropping half way in middle and then running parallel to ventral margin; in dorsal view with lateral margins postbasally projecting slightly, rounded until about mid-length, with left margin more distinctly narrowing than left margin, latter more strongly sclerotized.

*Female* (n=61) (Figs 30, 32): Antenna, cólour, and forewing pattern as in male; forewing length: 4.3–6.6 mm; frenulum with three acanthae; tibia with scale tuft not as strongly developed as that of male. Segment VII about twice length of preceding; sternum narrower and laterally more strongly sclerotized than tergum, with median depression apically.

Female genitalia (n=4) (Fig. 95). Papillae anales slightly elongate, with longer and thicker setae at base along dorsal and ventral narrow sclerotized bands. Posterior apophyses narrow, straight, about 2x longer that papillae anales. Intersegmental membrane forming wide, rounded projection dorsally, longer and wider than papillae anales. Anterior apophyses straight, narrow, about 3/4 length of posterior ones. Segment VIII narrowly sclerotized along base dorsally, with narrow sclerotized bands not touching medially, medially with spoon-shaped structure slightly projecting

ventrally from between narrow basal sclerotized bands until apex of segment, strongly sclerotized only along perimeter, apparently with tiny hole connecting with abdominal cavity medially at base; laterally with sclerotized area extending ventroposteriorly in band reaching posterior end of segment, but not touching other side ventromedially, with circular gap posterior to bases of anterior apophyses. Ostium bursae medio-ventrally in membranous area at base, just anterior to tiny sclerotized crescent. Ductus bursae narrow, entirely membranous, about as long as anterior apophyses. Corpus bursae large, about 2.4 X length of ductus bursae, potato shaped, with signum at posterior 1/3 followed posteriorly with rounded projection of corpus wall, spiculate on posterior part of projection and around it posteriorly and laterally; signum small, with eye-shaped base and short, finger-like, posteriorly directed projection; ductus seminalis from just anterior to signum.

BIOLOGY: This species was reared on *Croton scouleri* Hook. f. (Euphorbiaceae) as well as on *Exedeconus miersii* (Hook. f.) D'Arcy (Solanaceae), both endemic to the Galapagos. In the case of *E. miersii* caterpillars were feeding on the fruits. The moth comes to light, and specimens have been collected in all months of the year between the sea shore and the highest elevations, for example at 1341 m on the rim of the caldera of Fernandina.

DISTRIBUTION: Described from Cali, Colombia, and Huigra, Ecuador, this species is reported here for the first time since the original description. It is very widespread in the Galapagos, occurring on the islands of Española, Fernandina, Floreana, Genovesa, Isabela, Marchena, Pinta, Pinzon, Rabida, San Cristobal, Santa Cruz, Santa Fe, Santiago, Seymour Norte, Sombrero Chino, and Wolf.

REMARKS: The absence of a gnathos in this species makes it stand apart from the European species of the genus (see Elsner *et al.*, 1999). The presence of a spoon-shaped structure dorsally on segment VIII of the female is curious, but also found in European species (see Elsner *et al.*, 1999); possibly it serves to disperse pheromones.

***Compsolechia*** Meyrick, 1918

This is a large genus mostly represented in the Neotropical Region by 113 species (Becker, 1984). There is also one species in the Nearctic Region (Lee *et al.*, 2009) and some in Japan (Beccaloni *et al.*, 2003). The name is regarded as a synonym of *Anacampsis* Curtis by Vári *et al.* (2002). Host plants of *Compsolechia* species are recorded in the Krameriaceae, Melastomataceae, Rhizophoraceae, and Vochysiaceae (Robinson *et al.*, 2007), and *Compsolechia meibomiella* Forbes, 1931, was named from the host plant of the syntypes, *Meibomia*, a synonym of *Desmodium* Heist. ex Fabr. (Fabaceae).

***Compsolechia salebrosa*** Meyrick, 1918 Figs 33, 73, 96

*Compsolechia salebrosa* Meyrick, 1918: 140. – Meyrick (1925: 120); Clarke (1969a: 501, pl. 249 figs 2–2b); Becker (1984: 48).

MATERIAL EXAMINED: 31 ♂, 5 ♀, 3 of unrecorded sex. Male lectotype: 'Caldas, 4,400 feet, Colombia, Parish .5.14', Slide No. 5926 (BMNH). – *Fernandina*: SW side, 815 m elev., S 00° 21.270', W 091° 35.341'; North Side, 300 m, en yemas florales de Desmodium canum [sic]. – *Floreana*: Las Cuevas; close to Loberia, 6 m elev., S 01° 17.002', W 90° 29.460'; Cerro

del Asilo, 366 m elev., S 01° 18.931', W 90° 27.232'. – *Isabela, Darwin*: Tagus Cove; [W slope] 300 m elev.; [W slope] 1000 m elev.; 1200 m elev. – *Isabela, Sierra Negra*: 8.5 km N Puerto Villamil; 11 km N Puerto Villamil; ±15 km N Puerto Villamil. – *Pinta*: arid zone; 200 m elev.; 372 m elev., N 00° 34.476', W 90° 45.102'; 400 m elev. – *Pinzon*: Playa Escondida. – *San Cristobal*: 1 km S El Progreso; transition zone, SW El Progreso, 75 m elev., S 00° 56.359', W 89° 54.800'; antiguo botadero, ca. 4 km SE Puerto Baquerizo, 169 m elev., S 00° 54.800', W 089° 34.574'. – *Santa Cruz*: Charles Darwin Research Station; CDRS, wall of Invertebrates Lab., 11 m elev., S 00° 44.478', W 90° 18.132'; CDRS, Barranco, 20 m elev.; low agriculture zone, S 00° 42.132', W 90° 19.156'; transition zone, recently cut road, S 00° 42.528', W 90° 18.849'; agriculture zone, finca C. Troya, N Bella Vista, 294 m elev., S 00° 40.756', W 90° 18.671'. Deposited in the BMNH, CDRS, CNC, and MHNG.

DIAGNOSIS: This species is similar in general coloration to *C. lingulata* Meyrick, 1918, but the latter has no markings in the basal half of the forewing, except for the basal black spot on costa; its first costal marking is a postmedian, outwardly oblique black dash followed by white and black (see Clarke, 1969a: 488). *Compsolechia salebrosa* is similar in colour and pattern also to *C. succincta* Walsingham, 1910, described from Mexico, of which the holotype has no abdomen. *Compsolechia ptochogramma* Meyrick, 1922, is somewhat similar in colour to *C. salebrosa*, but it has fewer markings as a wide oblique dash from the base of the anal margin to above the fold, and a wide spot on costa subapically with a pair of short black streaks below, with white scales above and below the streaks. *Compsolechia meibomiella* Forbes, 1931, described from Cuba, is also similar to *C. salebrosa* in forewing pattern, but the subterminal line is closer to the middle of the wing, straighter, and more conspicuously bordered by black on its proximal side.

In the Galapagos this grey species with black and white forewing markings cannot be confused with any other, especially with regards to the medially dented postmedian line separating a paler apical section.

ADDITIONS TO ORIGINAL DESCRIPTION: *Male* (n=31) (Fig. 33): Scape without pecten. Ocelli present. Forewing length: 3.6–5.0 mm. Hindwing without hair pencil on costa, but latter slightly depressed near middle. Tibia with short scale tuft dorsally. Segment VII unmodified.

Male genitalia (n=3) (Fig. 73). Uncus compact, 1/3 length of tegumen, triangular in dorsal view, with short knob-like apex, dorsally with abundant setation of variable length, ventrally with short arms connecting with basal arms of gnathos. Gnathos with strongly sclerotized curved and short arms supporting large, strongly sclerotized egg-shaped ring with ventral, lightly sclerotized bulge inside ring. Tegumen bulky, with dorsal margin straight except slightly bulbous subapically, with two basal arms about as long as dorsal connection, with proximal ends of arms rounded and slightly curved downward, dorsally on bulbous part with short setae. Valva short, about as long as tegumen + uncus, narrow at base, ending in enlarged dorsal projection. Parabasal process thin, about half as long as valva, with few short setae toward apex medially. Vinculum poorly developed, ventrally leaving phallus mostly free, except at base, setose dorsally and laterally towards apex. Phallus bulky, about as long as whole genital capsule without phallus, not very strongly sclerotized, wide at proximal end, evenly narrowing to half basal girth, apically open ventrally and rounded; vesica with narrow cornutus about 1/4 length of phallus and ending in short ventral hook, partly spiculose.

*Female* (n=5): Antenna thinner than that of male; tibia, colour, and forewing pattern as in male; forewing length: 3.4–4.3 mm; frenulum with three acanthae. Segment VII about twice length of preceding, narrower, but not otherwise modified.

Female genitalia (n=2) (Fig. 96). Papillae anales almost circular, rather short, with narrow basal sclerotized bands wider dorsally, not connecting either dorsally or ventrally. Posterior and anterior apophyses narrow and straight, the latter slightly shorter. Segment VIII short, about 1/4 length of anal papillae, sclerotized only laterally and dorsally, forming basal narrow continuous band dorsally, with circular gaps of sclerotization at bases of anterior apophyses. Ostium bursae ventrally at base of segment VIII medially, without associated sclerotization. Ductus bursae very long, with posterior 1/5 very narrow, unsclerotized, lightly spiculose, median 3/5 narrow, unsclerotized, with spermatophore forming about 8 twists in both dissected specimens. Corpus bursae not clearly demarcated from ductus at first, elongate rounded, about 3/5 length of ductus, the two structures together longer than first seven abdominal segments, without signum, entirely spiculose, with short bulge near posterior end; inception of ductus seminalis at widest diameter, near anterior 1/4.

BIOLOGY: The larva was reared from flower buds of *Desmodium incanum* DC (Fabaceae) sampled on Fernandina. This is a native plant to the archipelago that also occurs in tropical areas around the world, although its origin is in tropical America (McMullen, 1999). The moth comes to lights and specimens have been collected from close to sea level to 1200 m in elevation during the months of February until May, and in October.

DISTRIBUTION: This species is widespread in the Galapagos. It has been found on the islands of Fernandina, Floreana, Isabela, Pinta, Pinzon, San Cristobal, and Santa Cruz. It is reported here from the first time since its description, which was based on specimens from Colombia and Guyana.

REMARKS: There is a possibility that *C. salebrosa* is a synonym of *C. succincta* Walsingham, 1910, but since the holotype of the latter has no abdomen, it may not prove possible to establish this fact. A revision of the entire genus would be more appropriate than here to solve this problem.

***Mesophleps*** Hübner, 1825

The Galapagos species, *Mesophleps adustipennis* (Walsingham), is the only representative of the genus in the Western Hemisphere (K. Sattler, pers. comm. to BL). It differs from *M. palpigera* (Walsingham), described from Mozambique, under which it was cited as a synonym by Forbes (1930), Becker (1984), and Lee *et al.* (2009) (see Diagnosis below). The synonymy of *Brachyacma* Meyrick, 1886 and *Mesophleps* was mentioned in Karsholt & Riedl (1996: 312). The generic combination '*Mesophleps adustipennis*' hasn't been used so far. It was graciously provided by Klaus Sattler (pers. comm. to BL), who is working on a revision of the genus.

The species of *Mesophleps* feed on Fabaceae, Dipterocarpaceae, and Rubiaceae (see Robinson *et al.*, 2007).

***Mesophleps adustipennis*** (Walsingham, 1897), **comb. n.** Figs 34, 74, 97
*Lathontogenus adustipennis* Walsingham, 1897: 88.
*Brachyacma palpigera* (Walsingham, 1891). – Forbes, 1930: 123. – Becker, 1984: 50).
? *Lipatia crotalariella* Busck, 1910. – Forbes, 1930: 123.

MATERIAL EXAMINED: Syntype ♂ from Grenada, dissected (label data not recorded). 3 ♂ (2 dissected), 38 ♀ (6 dissected) collected on the Galapagos Islands. – *Española*: Bahia Manzanillo; Punta Suarez. – *Floreana*: Las Cuevas; close to Loberia, 6 m elev., S 01° 17.002', W 90° 29.460'; Cerro del Asilo, 366 m elev., S 01° 18.931', W 90° 27.232'. – *Isabela, Sierra Negra*: 2 km W Puerto Villamil. – *Marchena*: [no specific locality]. – *Pinzon*: Playa Escondida, 14 m elev., S 00° 35.928', W 90° 39.291'. – *San Cristobal*: 4 km. SE Puerto Baquarizo [sic]; near Loberia, elev. 14 m, S 00° 55.149', W 89° 36.897'; transition zone, SW El Progreso, elev. 75 m, S 00° 56.359', W 89° 32.906'; antiguo botadero, ca. 4 km SE Puerto Baquerizo, 169 m elev., S 00° 54.800', W 89° 34.574'. – *Santa Cruz*: Estacion Cientifica Charles Darwin [ECCD]; ECCD, El Barranco, 22 m elev., S 00° 44.291', W 90° 18.107'; Finca S[teve]. Devine; transition zone, recently cut road, S 00° 42.528', W 90° 18. 849'; low agriculture zone, S 00° 42.132', W 90° 19.156'; Finca Vilema, 2 km W Bella Vista; Los Gemelos. – *Santiago*: La Bomba, 6 m elev., S 00° 11.151', W 90° 42.052'; N side, 437 m elev., S 00° 13.316', W 90° 43.808'; 200 m elev. Deposited in the BMNH, CDRS, CNC, and MHNG.

DIAGNOSIS: Externally this species is very similar to *Mesophleps palpigera* (Walsingham), but segment II of the labial palpus in *M. adustipennis* has a stronger dorsal tuft, is triangular in lateral view, in cross-section oval, and distally twice as thick as at the base whilst in *M. palpigera* it is round in cross-section and distally not much thicker than at base. The male genitalia of *M. adustipennis* differ in the round uncus (subrectangular in *M. palpigera*) and shorter, stouter gnathos hooks (K. Sattler, pers. comm. to BL). *Mesophleps adustipennis* is also the only species of the genus in the Western Hemisphere (K. Sattler, pers. comm. to BL).

In the Galapagos this species is most similar in size and colour to *Sitotroga cerealella* (Olivier) and *Dichomeris acuminatus* (Staudinger). It differs from them in the presence of a dark brown band along the costa from the middle of the forewing. Galapagos specimens vary substantially in size from 4.4 to 6.9 mm in forewing length in males, and 4.4 to 8.1 mm in females.

BIOLOGY: In the Galapagos the species has been reared from fruits of *Prosopis juliflora* (Sw.) DC. (specimen in CDRS) (Fabaceae) and from *Leucaena leucocephala* (Lam.) de Wit, the lead tree (Fabaceae), on Santa Cruz by M.-L. Johnson (specimens in Australian National Insect Collection, Canberra). If *M. crotalaria* (Busck, 1910) is a synonym of *M. adustipennis*, then the caterpillar has been recorded to feed also in *Crotalaria* pods (Fabaceae) (Forbes, 1930). Moths come to light and specimens have been collected from January until May and in September, October, and December mostly near sea level but also until 580 m in elevation (Los Gemelos) on the Galapagos.

DISTRIBUTION: Widely spread in the Galapagos archipelago, this species has been collected on the islands of Española, Floreana, Isabela, Marchena, Pinzon, San Cristobal, Santa Cruz, and Santiago. If this species is the same as *M. crotalaria* (Busck), then it also occurs on Trinidad, St. Thomas, and St. Croix in the Caribbean (Forbes, 1930).

REMARKS: A comparison of a male syntype of *M. adustipennis* with Galapagos specimens showed a perfect match in male genitalia and labial palpus. A lectotype will be designated by K. Sattler in a forthcoming revision of the genus (pers. comm. to BL).

***Untomia*** Busck 1906

Becker (1984) and Lee *et al.* (2009) respectively record seven species of *Untomia* for the Neotropical fauna and five species for the Nearctic fauna, none of

which were listed for both regions. Beccaloni *et al.* (2003) list a total of eight valid species of *Untomia*, all found in the Western Hemisphere. Not all species listed from the Neotropics by Becker (1984) belong in *Untomia* (K. Sattler, pers. comm. to BL), and *U. juventella* (Walsingham, 1897) was transferred to *Helcystogramma* by Hodges (1986). The European species of *Syncopacma* have similar wing pattern and genitalia (Elsner *et al.*, 1999) to those of the Galapagos species of *Untomia*, and *Syncopacma* Meyrick, 1925, described for a South African species, may be a synonym of *Untomia* (K. Sattler, pers. comm. to BL). All species of *Untomia* and *Syncopacma* of the Western Hemisphere and Europe and all Neotropical species of *Anacampsis* as well as those occurring in the south of the USA were checked to conclude that the Galapagos species was new. There are no host records available for *Untomia*, but Robinson *et al.* (2007) give several hosts for *Syncopacma* species, all in Fabaceae, except for one in Asteraceae.

***Untomia lunatella*** Landry, sp. n. Figs 35, 36, 75, 98

HOLOTYPE: ♂, 'ECU., GALAPAGOS | Isabela, nr Tagus Cove | 100 m. elev[ation]., 21.v.1992 | M[ercury]V[apour]L[amp], leg[it]. B. Landry', 'HOLOTYPE | Untomia | lunatella | B. Landry'. Specimen in excelllent condition. Deposited in the MHNG.

PARATYPES: 11 ♂, 22 ♀ from the Galapagos Islands, Ecuador. – *Floreana*: 1 ♂ (dissected, slide MHNG ENTO 6031), Las Cuevas, 23.iv.1992, M[ercury]V[apour]L[amp] (B. Landry).– *Isabela, Alcedo*: 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 6033), lado NE, low arid zone, bosq[ue], palo santo, 18.iv.2002, u[ltra]v[iolet]l[ight] (B. Landry, L. Roque); 1 ♀, NE slope, near pega-pega camp, GPS: elev. 483 m, S 00° 24.029', W 91° 02.895', 31.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♀, Guayabillos, 700 m [elevation], 16.iv.2002, l[ampe]u[ltra] v[iolette] (B. Landry, L. Roque). – *Isabela, Darwin*: 1 ♀, Tagus Cove, 13.v.1992, MVL (B. Landry). – *Isabela, Sierra Negra*: 1 ♂, 1 ♀ Puerto Villamil, 2.iii.1989, MVL (B. Landry). – *Marchena*: 1 ♂, [no specific locality], 12.iii.1992, MVL (B. Landry). – *Pinta*: 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 6032), Plaja Ibbeston [sic], 13.iii.1992, MVL (B. Landry); 1 ♂ (dissected, MHNG ENTO 5368), same data except 14.iii.1992; 3 ♂, 3 ♀, Cabo Ibbetson, 8 m elev[ation]., N 00° 32.819', W 90° 44.229', 15.iii.2006, uvl (P. Schmitz, L. Roque); 1 ♀, arid zone, 15.iii.1992, MVL (B. Landry).; 1 ♀ (dissected, slide MHNG ENTO 5369), ±50 m elev., 20.iii.1992, MVL (B. Landry). – *Pinzon*: 1 ♀, plaja Escondida, 20.iv.2002, uvl (B. Landry, L. Roque). – *San Cristobal*: 5 ♀ (one dissected, slide BL 1671), P[uer]to Baquarizo [sic], 17.ii.1989, MVL (B. Landry). – *Santa Cruz*: 1 ♀, C[harles]D[arwin]R[esearch]S[tation], wall of Invert[ebrate]s. Lab., GPS: 11 m elev., S 00° 44.478', W 90° 18.132', 19.iii.2004, uvl (B. Landry, P. Schmitz); 1 ♀, CDRS, Barranco, 20 m elev., 30.iv.2002, uvl (B. Landry); 1 ♂ (dissected, slide MHNG ENTO 6034), 1 ♀, E[stacion]C[ientifica]C[harles]D[arwin], 22 m elev., S 00° 44.291', W 90° 18.107', 23.iii.2006, uvl (P. Schmitz); 1 ♀, transition zone, recently cut road, GPS: S 00° 42.528', W 90° 18.849', 12.iii.2004, uvl (B. Landry, P. Schmitz). – *Santa Fe*: 1 ♂, Tourist trail, 28.v.1992, MVL (B. Landry). – *Santiago*: 1 ♀ (dissected, slide MHNG ENTO 6035), Bahía Espumilla, 4.iv.1992, MVL (B. Landry). Deposited in the BMNH, CDRS, CNC, and MHNG.

ETYMOLOGY: The name is derived from the shape of the white, postmedian forewing markings, which resemble a pair of crescents usually touching each other along the wing's midline.

DIAGNOSIS: The dark brown forewing pattern with a postmedian pair of white crescents usually joined medially is unique among Galapagos Gelechiidae and other microlepidoptera.

Several species, notably *Syncopacma* species from Europe, have a dark brown forewing with a complete or incomplete postmedian line, but in all European species

this line is straight. Some North American species with this pattern are placed in genus *Anacampsis*. The most similar are *A. agrimoniella* (Clemens, 1860), described from Pennsylvania, USA, and *A. lupinella* Busck, 1901 (some specimens only), described from Ontario, Canada, but in both of these species the postmedian line is straight, although it can be incomplete in the latter.

DESCRIPTION: *Male* (n=12) (Fig. 35). Head with ocelli, greyish brown with copper lustre, mostly with large scales converging toward middle, also with tiny white scales along eye margin. Haustellum greyish brown. Maxillary palpus dark brown and white. Labial palpus with basal segment greyish brown; segment II mostly dark brown laterally and white medially with dark brown toward apex; segment III longitudinally striped dark brown and white. Antennal scape without pecten, striped dark brown and white; pedicel coloured as scape; flagellum dark brown with white stripe on basal half. Thorax mostly coloured as head, metathorax paler greyish brown. Foreleg coxa and femur greyish brown; tibia dark brown; tarsus dark brown with white apical ring on tarsomeres I–IV. Midleg as in foreleg, except tibia with some white scales at apex. Hindleg as preceding legs, except tibia with white patches at bases of spurs and with greyish-brown tuft on dorsal edge. Forewing length: 3.3–4.0 mm (Holotype: 4.0 mm). Forewing with basal third greyish brown, distal 2/3 dark brown, with small black and white spot in fold at 1/3, with pair of crescent-shaped ivory-white markings usually joined medially from costa and dorsum at 2/3; fringe with first row of scales shining snow white on basal 2/3 and dark brown at tip, second row longer, greyish brown. Hindwing brown with concolorous fringe. Abdomen brown dorsally and iridescent, greyish brown ventrally; segment VIII unmodified.

Male genitalia (n=4) (Fig. 75). Uncus about half as long as tegumen, tube like (of equal width for whole length), bent almost at right angle from middle, with 4 short, strongly sclerotized pegs pointing down at apex, abundantly setose. Gnathos strongly sclerotized, bent at right angle from middle, with shortly upturned apex. Tegumen narrow, with dorsal margin straight, ventral margins slightly produced ventrally, widely rounded, with pair of short setae near margin on ventral flanges, and lateral margins slightly expanding from base to apex, with apex almost twice as wide as base. Valva narrow, of same girth for whole length, slightly upturned from middle, moderately sclerotized and setose, membrane between bases of valvae adorned with few short to long setae. Vinculum laterally reduced, narrow, laterally compressed and crescent shaped with posterior edge adorned with moderately long setae; ventrally quadrangular, slightly longer than wide, with straight apical and lateral margins, with anterior margin slightly concave, apically with digit-like projections slightly shorter than ventral base, slightly curving medially, with few tiny setae laterally near apex, with short, laterally compressed apex. Phallus disposed tightly against ventral part of vinculum, leaving wide gap between it and bases of valvae, straight, without coecum penis, gently diminishing in girth toward apex, distal half asymmetrical, with right side membranous, narrowly rounded at apex.

*Female* (n=22) (Fig. 36): Antenna, wing pattern, and colour as in male. Frenulum with 2 acanthae. Forewing length: 2.9–4.0 mm. Segment VII unmodified except for concave apical margins.

Female genitalia (n=4) (Fig. 98). Papillae anales short, almost evenly broadly rounded, moderately setose, with short, thin sclerotized band at base ventrally and dorsally from bases of posterior apophyses. Latter thin, straight, reaching basal margin of segment VIII. Anterior apophyses shorter, slightly curved, as thin and half as long as posterior ones. Segment VIII slightly longer than papillae, sclerotized for whole length laterally except circular gap dorsally from base of anterior apophyses, with apical margins broadly rounded; dorsally with sclerotized area narrower, with shallow median circular depression with rugged surface; ventrally membranous medially, with lateral sclerotized areas forming dorsal and ventral triangular projections almost touching ventrally near middle. Ostium bursae at base of segment VIII medially, without associated sclerotization. Ductus bursae short and mostly membranous and spiculate, with narrow posterior end slightly funnel shaped and lightly sclerotized, with anterior 1/4 slightly enlarging toward corpus bursae. Latter slightly elongate, prune shaped, with posterior half spiculose, without signum, with inception of ductus seminalis posteriorly set, close to connection with ductus bursae, with most of posterior half spiculose.

BIOLOGY: Unknown except that specimens were attracted to light mostly near sea level, but also at higher elevations, up to 700 meters, from February until May.

DISTRIBUTION: Apparently endemic to the Galapagos, this species is widespread, with records from Floreana, Isabela, Marchena, Pinta, Pinzon, San Cristobal, Santa Cruz, Santa Fe, and Santiago.

REMARKS: This is the only Galapagos species of Gelechiidae for which the frenulum of the female has two acanthae, the others having three.

**Pexicopiinae**

***Sitotroga*** Heinemann, 1870

A small genus of three species. Its most commonly encountered species, a pest of stored grains distributed around the planet, is treated below. It has been recorded numerous times in checklists and taxonomic treatments of Gelechiidae on all continents.

***Sitotroga cerealella*** (Olivier, 1789) Figs 37, 76, 77, 99

*Alucita cerealella* Olivier, 1789: 121, pl. 93 fig. 8.

*Sitotroga cerealella* (Olivier). – Meyrick, 1925: 38. – Forbes, 1930: 115, 116. – Zimmerman, 1978: 1738–1741, figs 1294–1297. – Becker, 1984: 49. – Lee *et al.*, 2009: 32.

MATERIAL EXAMINED: Several specimens in the BMNH and MHNG. 9 specimens (sexes not noted) collected on one Galapagos Island. – Santa Cruz: Puerto Ayora, en arroz grano. (CDRS).

DIAGNOSIS: This species can be separated from the other two members of the genus as follows: *S. horogramma* (Meyrick, 1921) described from Fiji, has the forewing with a dark brown line along the costa, interrupted subapically, another along the terminal margin, and a small spot sometimes at 2/3 medially. *Sitotroga psacasta* (Meyrick, 1908), described from the Transvaal, South Africa, has brown markings on the forewing as a spot or long dash submedially on the fold, a costal spot at 2/3, and a line subterminally, parallel to termen.

In the Galapagos this species is most similar to *Mesophleps adustipennis* (Walsingham) and *Dichomeris acuminatus* (Staudinger) from which it can be separated by the presence of a pecten on the antennal scape and other features (see diagnosis of *D. acuminatus* below). This is the only Galapagos species of Gelechiidae adorned with a scape pecten.

BIOLOGY: The larva and pupa have been illustrated by Zimmerman (1978), who also reported on the larval behaviour. The species is a long recognized pest of grains either in the field or in storage. The larva has been reported to feed on barley, corn, rice, wheat, and other Poaceae, but also on beans and peas (Fabaceae) (Zimmerman, 1978).

In the Galapagos specimens were reared on rice grains.

DISTRIBUTION: *Sitotroga cerealella* is widely distributed in temperate to tropical regions around the world, probably everywhere humans have been growing and storing grains and have been in commercial contact with Europeans. In the Galapagos it has been found so far only on the island of Santa Cruz.

REMARKS: The specimen illustrated here was collected in Switzerland. Known as the Angoumois grain moth, this species has six known synonyms (see Beccaloni *et al.*, 2003). The references cited above do not represent an exhaustive list, but are those used elsewhere here.

**Dichomeridinae**

***Dichomeris*** Hübner, 1818

A large genus with several hundred species and 79 known generic synonyms (see Hodges, 1986). It is rich in species in all areas around the World except Australia, and there are no native species in the Pacific Islands and New Zealand. The caterpillars are leaf tiers and feed on a variety of plant families.

***Dichomeris acuminatus*** (Staudinger, 1876) Figs 38, 78, 79, 100

*Mesophleps* ? *acuminatus* Staudinger, 1876: 148.

*Dichomeris acuminatus* [or *acuminata*] (Staudinger). – Zimmerman, 1978: 1706–1713, figs 1262–1267. – Becker, 1984: 50. – Hodges, 1986: 38–40, pl. 4 fig. 1, text fig. 9.

MATERIAL EXAMINED: Several specimens in the BMNH. 13 ♂ (1 dissected), 10 ♀ (1 dissected) collected on the Galapagos Islands. – *Española*: Bahia Manzanillo. – *Isabela, Alcedo*: NE slope Alcedo, near shore, 9 m elev., S 00° 23.619', W 90° 59.715'; NE slope Alcedo, 292 m elev., S 00° 23.829', W 91° 01.957'. – *Isabela, Darwin*: Tagus Cove; 630 m elev. – *Marchena*: [no specific locality]. – *Pinta*: Plaja Ibbeston [sic]; arid zone; ±50 m elev.; 400 m elev. – *Rabida*: Tourist trail. – *Santa Cruz*: Estacion Cientifica Charles Darwin. – *Santiago*: La Bomba, 6 m elev., S 00° 11.151', W 90° 42.052'. Deposited in the BMNH, CDRS, CNC, and MHNG.

DIAGNOSIS: This species belongs to the '*acuminata* group' of *Dichomeris* (Hodges, 1986) composed of one additional taxon, i.e. *D. nenia* Hodges distributed in the Southeast of the USA. These can be separated by the pale orange scales above the eye in *D. acuminatus*, medium to dark grey in *D. nenia*, the smooth median margins of the lobes of the juxta in *D. acuminatus* (Fig. 78), serrate in *D. nenia*, and in the female genitalia, by the antrum with the ventral plate shorter than broad in *D. acuminatus* (Fig. 100), longer than broad in *D. nenia*.

In the Galapagos this species is most similar to *Mesophleps adustipennis* (Walsingham) and *Sitotroga cerealella* (Olivier). The three can be separated by the

presence of dark brown scaling on the distal half of the forewing costa in *M. adustipennis*, and the presence of a pecten on the antennal scape in *S. cerealella*. In addition, *D. acuminatus* has a large, anteriorly produced ventral scale tuft on the second labial palp segment whereas there is a scale tuft only dorsally in *M. adustipennis* and none in *S. cerealella*. The Galapagos specimens available vary in forewing length from 4.7 to 5.3 mm in males, and 3.8 to 5.1 mm in females. The forewing submedian and post-median spots along midline are rarely expressed more strongly than in the specimen illustrated here.

BIOLOGY: The larva has been recorded to feed on many different species of Fabaceae such as *Cajanus cajan* (L.) Huth (pigeon pea), *Cyamopsis* species, *Desmodium gyroides* de Candolle (indigo), *Medicago sativa* L. (alfalfa), *Sesbania sericea* (Willdenow) de Candolle, and *Tephrosia* species (Hodges, 1986). The species has been known to reach pest status on alfalfa and indigo. Robinson *et al.* (2007) also list species of *Aeschynomene*, *Glycine*, *Indigofera*, *Lotus*, *Pisum*, and *Trifolium*. The larva and pupa have been illustrated by Zimmerman (1978). In the Galapagos the specimens were collected at light from the sea shore to 630 m in elevation in the months of March, April, and May.

DISTRIBUTION: Widely distributed in tropical and subtropical regions around the world, *D. acuminatus* has been collected on the islands of Española, Isabela, Marchena, Pinta, Rabida, Santa Cruz, and Santiago of the Galapagos archipelago.

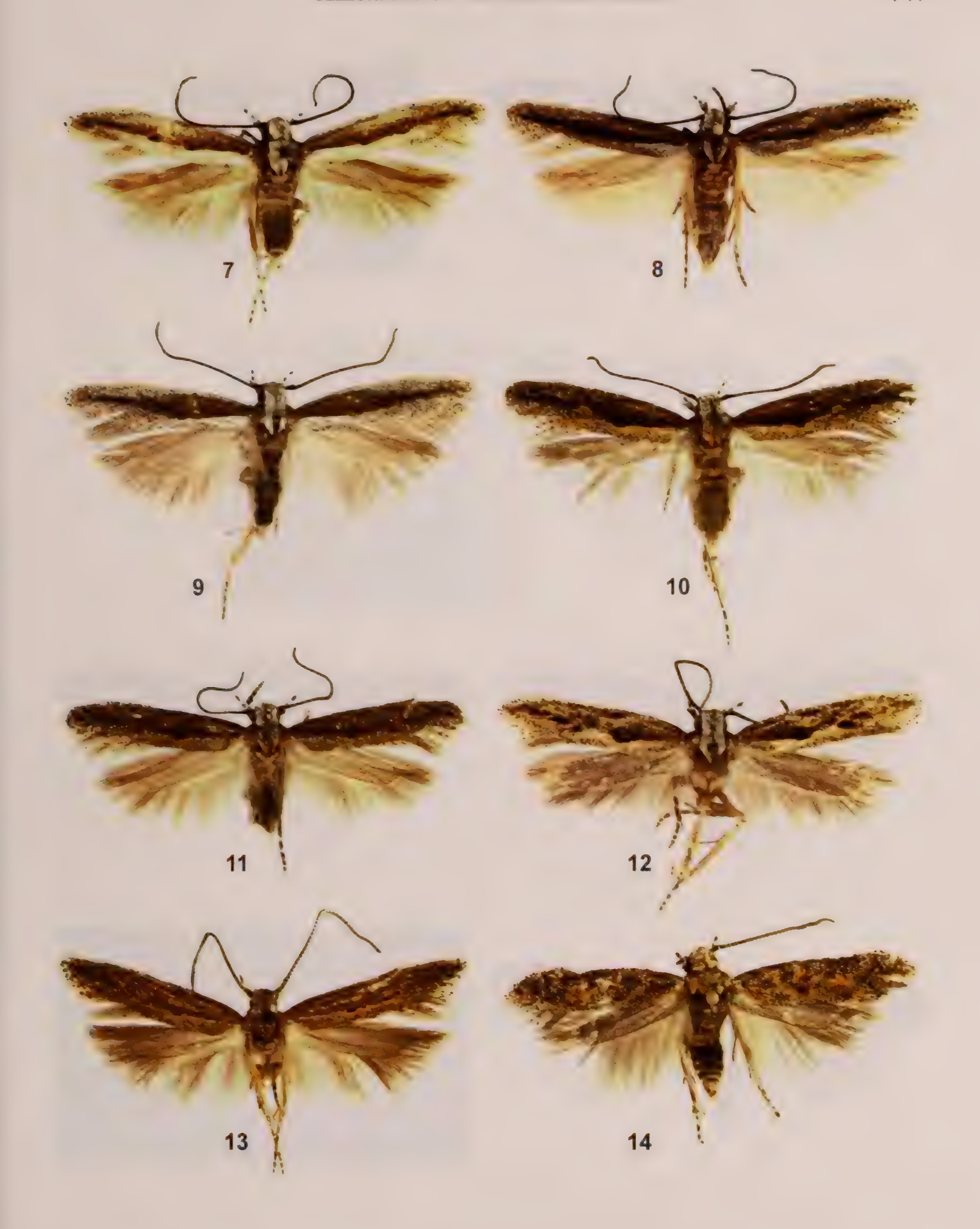
REMARKS: This species was first described from Sicily, Italy. Five synonyms, based on specimens described from Réunion, St. Vincent, France, Australia, and Sri Lanka are known (see Hodges, 1986: 38).

The male dissected from the Galapagos was collected at Tagus Cove, near the sea shore, on the west side of Isabela at the base of Volcan Darwin. Its phallus has a rather long cornutus, such as that illustrated by Zimmerman (1978), which contrasts with the shorter one illustrated by Hodges (1986). Specimens from Gambia, Japan, and Morocco in the BMNH also show a long cornutus.



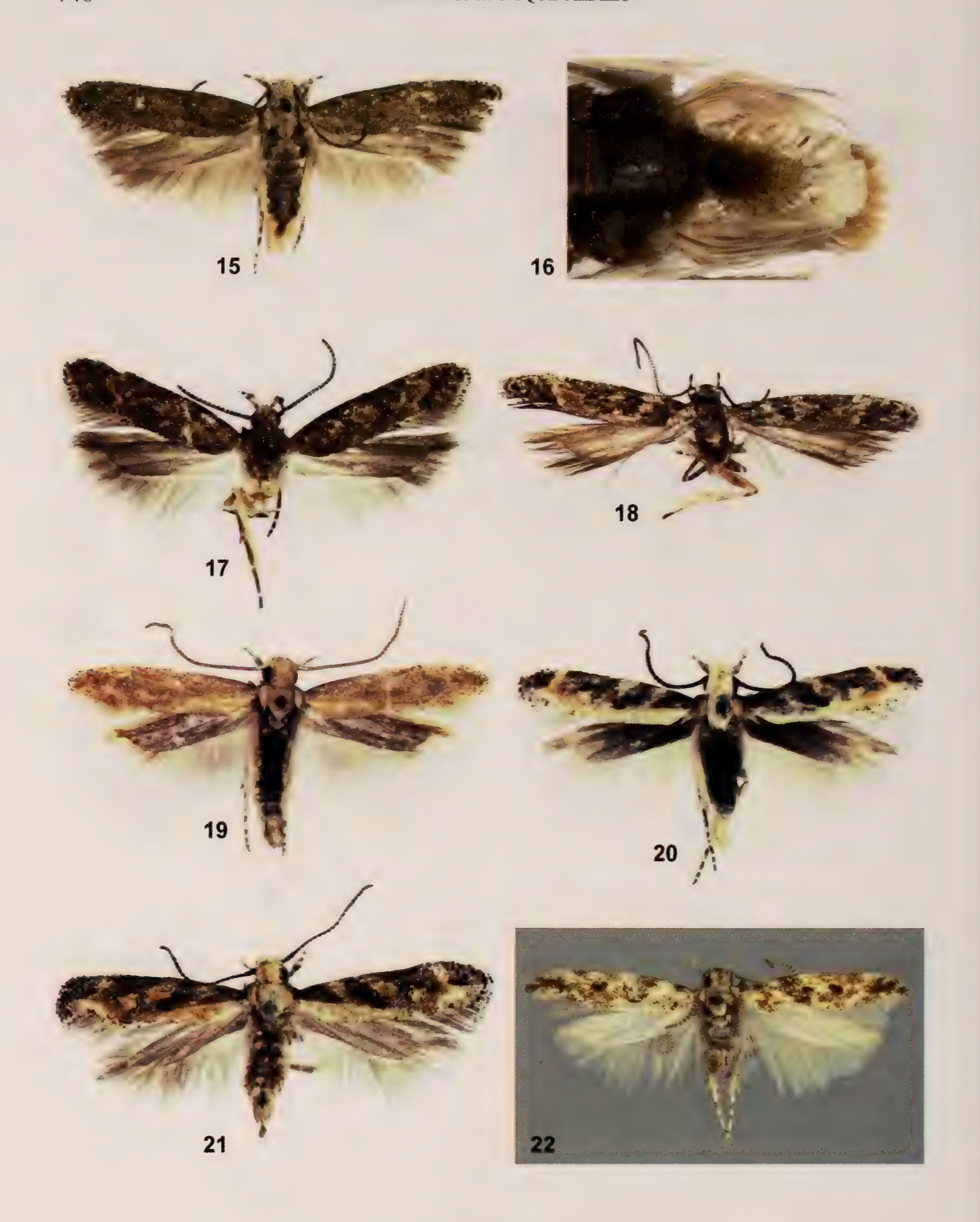

FIGS 1–6

Adults of Galapagos Gelechiini. (1) *Aristotelia naxia*: ♀, Isabela, 11.iii.1989, CNC. (2–3) *Aristotelia sarcodes*: (2) ♂, San Cristobal, 16.ii.2004, MHNG. (3) ♂, under side of wings with hair pencil extended. (4) *Chionodes stefaniae*: ♂ holotype, MHNG. (5) *Stegasta zygotoma*: ♂, Santa Cruz, 7.iii.1992, MHNG. (6) *Stegasta francisci*: ♀ paratype, Isabela, 20.v.1992, MHNG.




FIGS 7–14

Adults of Galapagos Gnorimoschemini. (7–12) *Ephysteris sporobolella*. (7) ♂ holotype, MHNG. (8) ♀ paratype, Santa Fe, 28.v.1992, MHNG. (9) ♂ paratype, Isabela, 30.iii.2004, MHNG. (10) ♀ paratype, San Cristobal, 15.iii.2004, MHNG. (11) ♀ paratype, Isabela, 16.v.1992, MHNG. (12) ♂ paratype, Wolf, 7.ii.2002, CDRS. (13) *Ephysteris scimitarella*: ♂ holotype. (14) *Ephysteris subdiminutella*: ♂, Santiago, 1.iii.2005, MHNG.



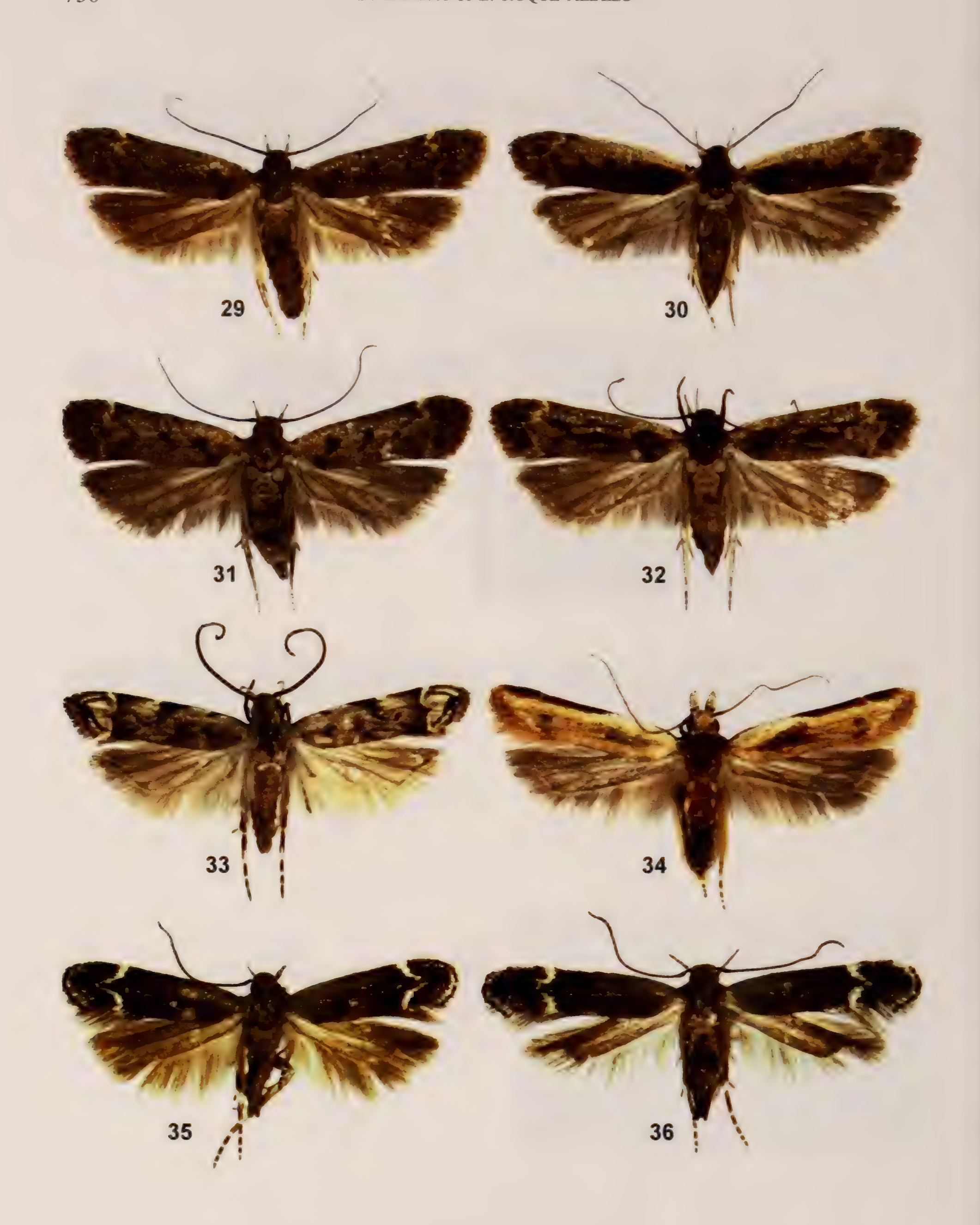

FIGS 15–22

Adults of Galapagos Gnorimoschemini. (15–16) *Phthorimaea perfidiosa*. (15) ♂, Genovesa, 25.iii.1992, MHNG. (16) Apex of ♂ abdomen. (17) *Phthorimaea absoluta*: ♂, San Cristobal, 27.xi.2001, CDRS. (18) *Scrobipalpula densata*: ♂, Sombrero Chino, 6.vii.1998, CDRS. (19) *Scrobipalpula inornata*: ♂ paratype, Santa Cruz, 13.iii.2004, MHNG. (20–21) *Scrobipalpula equatoriella*. (20) ♂ holotype. (21) ♀ paratype, Santa Cruz, 19.iii.2004, MHNG. (22) *Scrobipalpula caustonae*: ♂ holotype.




FIGS 23–28

Adults of Galapagos Gnorimoschemini and Litini. (23–26) *Symmetrischema escondidella*. (23) ♂ paratype, Pinzon, 27.iii.2006, MHNG. (24) ♀ paratype, Plaza Sur, 14.iv.2006, MHNG. (25) Head. (26) Underside of ♂ wings. (27–28) *Agnippe omphalopa*: (27) ♂, Isabela, 3.iii.1989, CNC; (28) ♀, Pinzon, 20.iv.2002, MHNG.



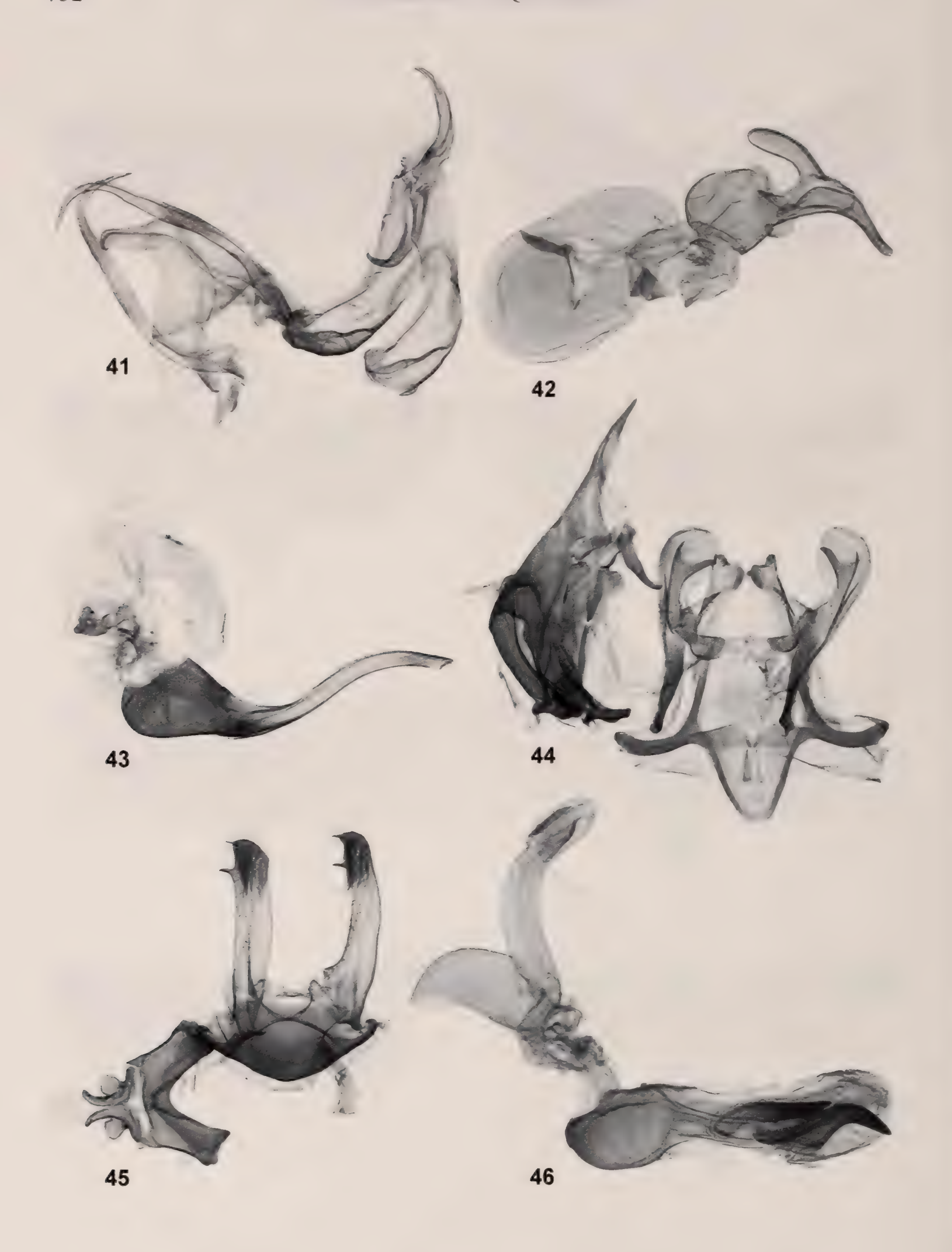

FIGS 29–36

Adults of Galapagos Anacampsini. (29–32) *Anacampsis primigenia*. (29) ♂, Pinzon, 20.iv.2002, MHNG; (30) ♀, Pinzon, 20.iv.2002, MHNG. (31) ♂, San Cristobal, 16.iii.2004, MHNG. (32) ♀, Pinta, 17.iii.1992, MHNG. (33) *Compsolechia salebrosa*: ♂, Isabela, 9.iii.1989, CNC. (34) *Mesophleps adustipennis*: ♂, San Cristobal, 15.iii.2004, MHNG. (35–36) *Untomia lunatella*: (35) ♂ holotype; (36) ♀ paratype, Santa Cruz, 19.iii.2004, MHNG.



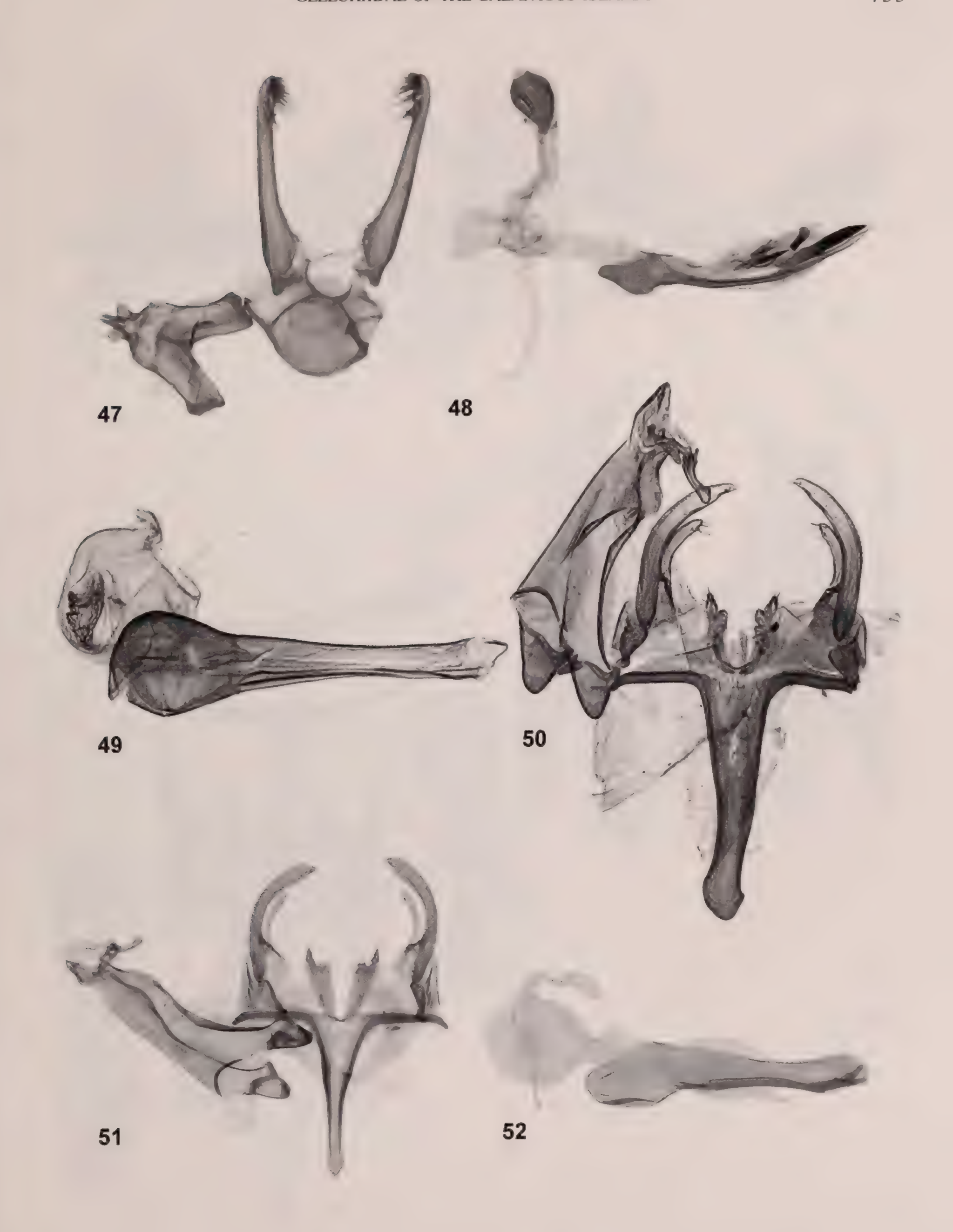

Figs 37–40

Adults of Galapagos Pexicopiinae, Dichomeridinae, and undetermined Gnorimoschemini. (37) *Sitotroga cerealella*: ♂, Switzerland, Tessin, Locarno, MHNG. (38) *Dichomeris acuminatus*: ♂, Pinta, 13.iii.1992, MHNG. (39–40) Gnorimoschemini spp.: (39) ♀, Española, 2.v.1992, MHNG, forewing length = 3.7 mm; (40) ♀, Santa Cruz, 18.ii.2005, MHNG, forewing length = 3.3 mm.



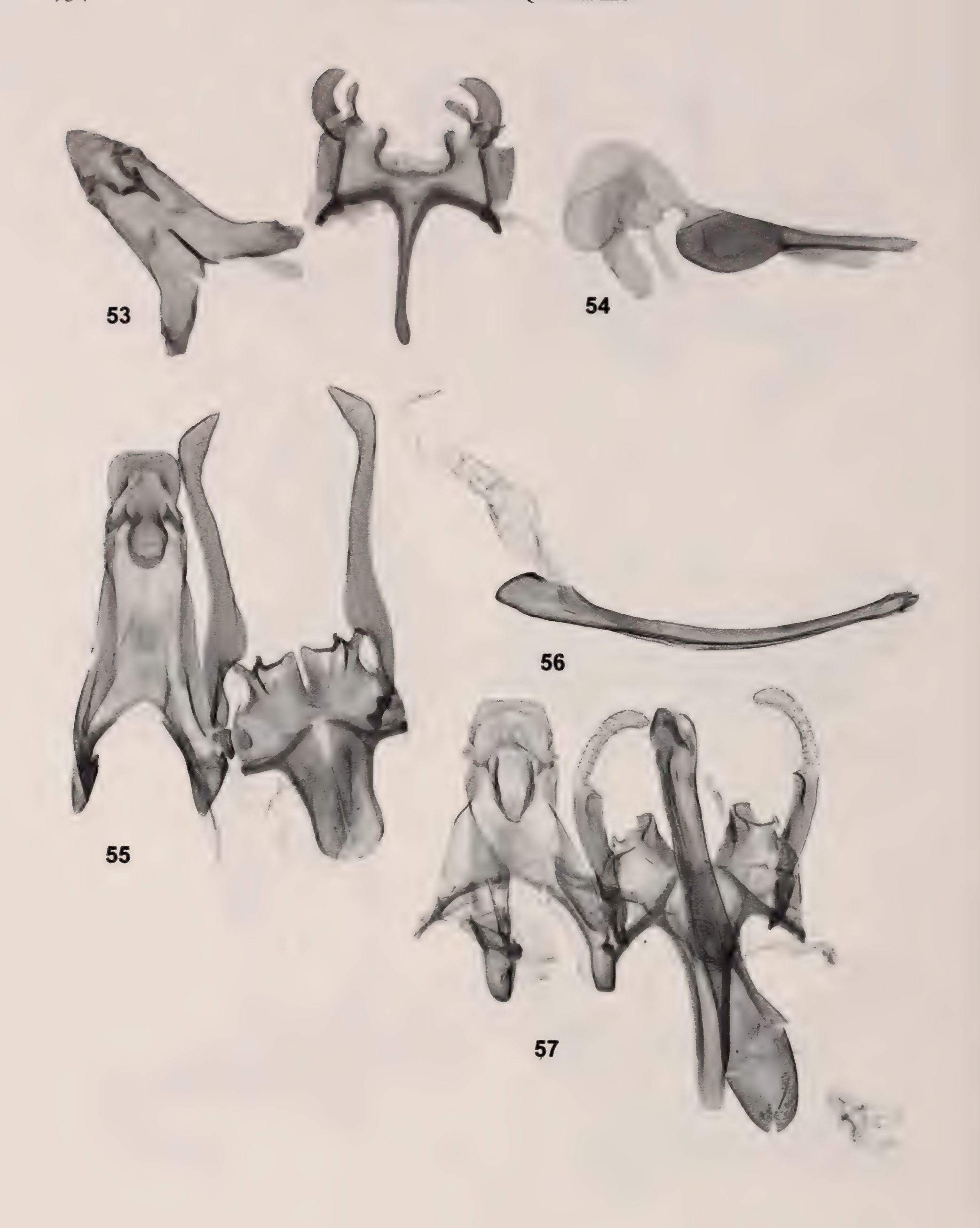

FIGS 41–46

Male genitalia of Galapagos Gelechiinae. (41–42) *Aristotelia naxia*, slide MHNG ENTO 5354. (41) Genitalia without phallus. (42) Phallus. (43–44) *A. sarcodes*, slide MHNG ENTO 4904: (43) Phallus. (44) Genitalia without phallus. (45–46) *Stegasta zygotoma*, slide MHNG ENTO 5358. (45) Genitalia without phallus. (46) Phallus.




FIGS 47–52

Male genitalia of Galapagos Gelechiinae. (47–48) *Stegasta francisci*, slide MHNG ENTO 5953: (47) Genitalia without phallus. (48) Phallus. (49–50) *Ephysteris sporobolella*, slide MHNG ENTO 4925. (49) Phallus. (50) Genitalia without phallus. (51–52) *E. scimitarella*, holotype. (51) Genitalia without phallus; (52) Phallus.



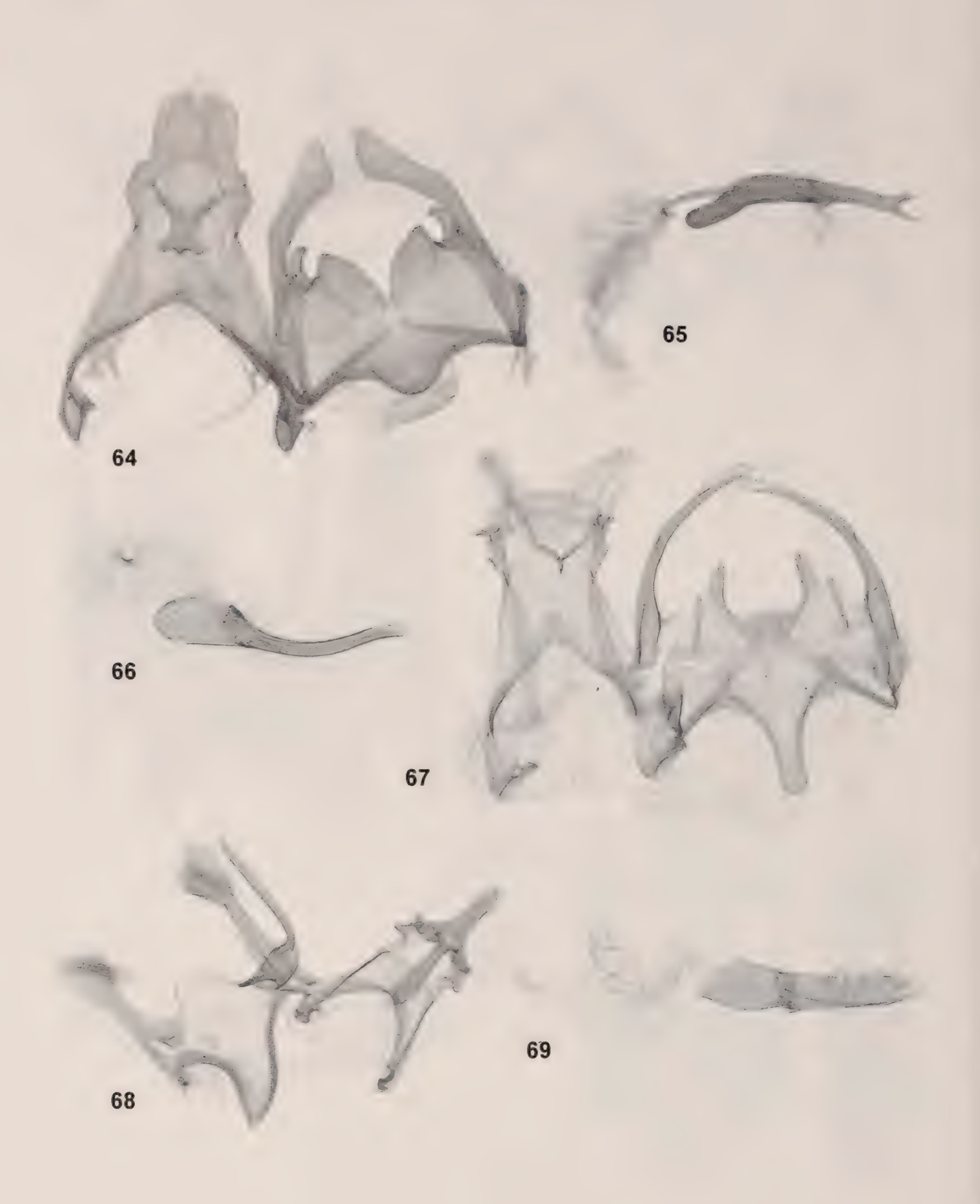

FIGS 53–57

Male genitalia of Galapagos Gelechiinae. (53–54) *Ephysteris subdiminutella*, slide MHNG ENTO 4929. (53) Genitalia without phallus. (54) Phallus. (55–56) *Phthorimaea perfidiosa*, slide MHNG ENTO 5947. (55) Genitalia without phallus. (56) Phallus. (57) *Phthorimaea absoluta*, slide BL 1424 (CDRS), whole genitalia.



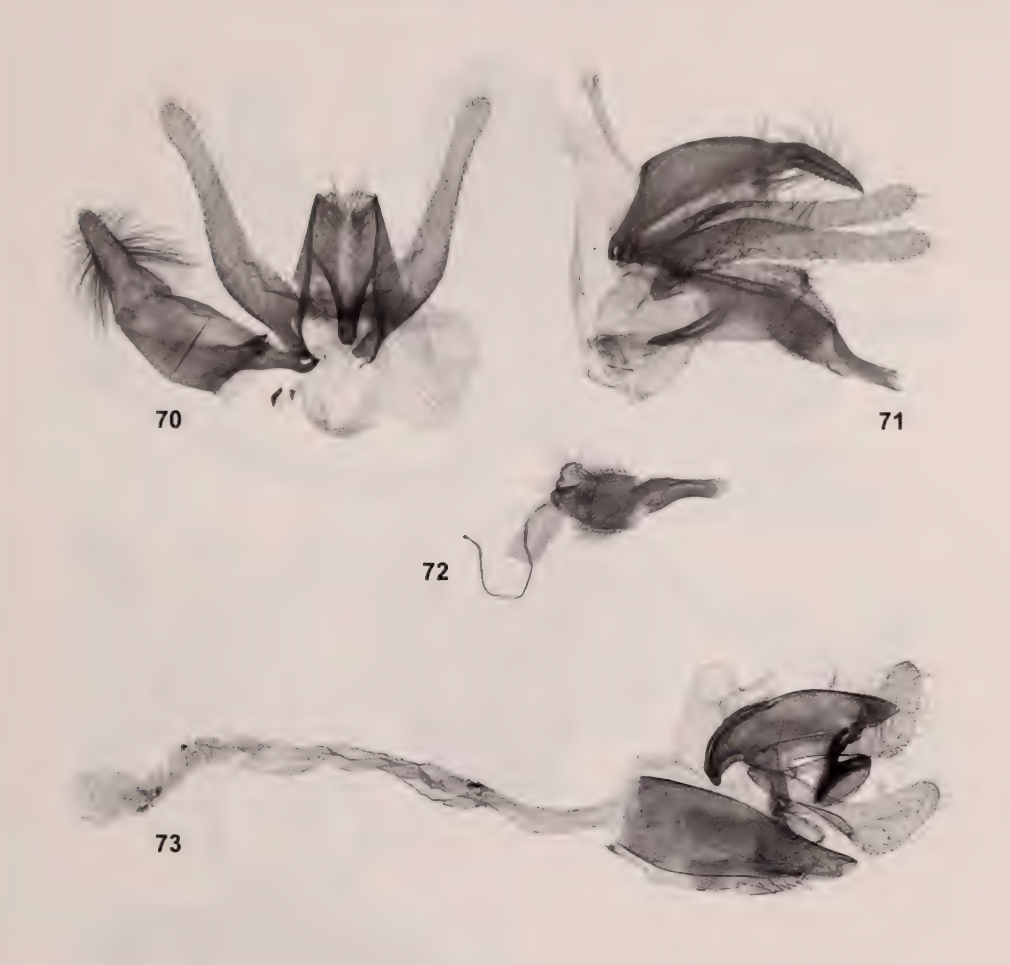

FIGS 58–63

Male genitalia of Galapagos Gelechiinae. (58–59) *Scrobipalpula densata*, slide BL 1668 (CDRS). (58) Genitalia without phallus. (59) Phallus. (60–61) *Scrobipalpula inornata*, slide MHNG ENTO 5359. (60) Phallus. (61) Genitalia without phallus. (62–63) *S. equatoriella*. (62) Genitalia without phallus, slide BMNH Microlep. 29741. (63) Phallus, slide MHNG ENTO 5960.




FIGS 64–69

Male genitalia of Galapagos Gelechiinae. (64–65) *Scrobipalpula caustonae*, slide MHNG ENTO 5360. (64) Genitalia without phallus. (65) Phallus. (66–67) *Symmetrischema escondidella*, slide MHNG ENTO 5976. (66) Phallus. (67) Genitalia without phallus. (68–69) *Agnippe omphalopa*, slide MHNG ENTO 5371. (68) Genitalia without phallus. (69) Phallus.




FIGS 70–73

Male genitalia of Galapagos Gelechiinae. (70–72) *Anacampsis primigenia*. (70, 72) Genitalia without phallus (70) and phallus (72), slide MHNG ENTO 5365. (71) Genitalia in side view, slide MHNG ENTO 6026. (73) *Compsolechia salebrosa*, slide MHNG ENTO 6030, whole genitalia in side view.




FIGS 74–75

Male genitalia of Galapagos Gelechiinae. (74) *Mesophleps adustipennis*, slide MHNG ENTO 6016, whole genitalia, spread in apical view. (75) *Untomia lunatella*, slide MHNG ENTO 6033, whole genitalia in side view.




FIGS 76–79

Male genitalia of Galapagos Pexicopiinae and Dichomeridinae. (76–77) *Sitotroga cerealella*, slide MHNG ENTO 6020. (76) Genitalia without phallus. (77) Phallus. (78–79) *Dichomeris acuminatus*, slide MHNG ENTO 5361. (78) Genitalia without phallus. (79) Phallus.




FIGS 80–83

Female genitalia of Galapagos Gelechiinae. (80–82) *Aristotelia naxia*. (80) Slide MHNG ENTO 4955. (81) Specimen in lactic acid, unmounted. (82) Slide MHNG ENTO 4953. (83) *A. sarcodes*, slide MHNG ENTO 4905.




FIGS 84–87

Female genitalia of Galapagos Gelechiinae. (84) *Stegasta francisci*, slide MHNG ENTO 5954. (85) *Ephysteris sporobolella*, slide MHNG ENTO 4916. (86) *E. scimitarella*, slide BL 1669 (CNC). (87) *E. subdiminutella*, slide MHNG ENTO 5991.




FIGS 88–91

Female genitalia of Galapagos Gelechiinae. (88) *Phthorimaea perfidiosa*, slide MHNG ENTO 5946. (89) *Phthorimaea absoluta*, slide MHNG ENTO 4921. (90) *Scrobipalpula ?densata*, slide BL 1178 (CDRS). (91) *Scrobipalpula inornata*, slide MHNG ENTO 5957.




FIGS 92–94

Female genitalia of Galapagos Gelechiinae. (92) *Scrobipalpula equatoriella*, slide MHNG ENTO 5961. (93) *Symmetrischema escondidella*, slide MHNG ENTO 5975. (94) *Agnippe omphalopa*, slide MHNG ENTO 5372.




Figs 95–97

Female genitalia of Galapagos Gelechiinae. (95) *Anacampsis primigenia*, slide MHNG ENTO 5364. (96) *Compsolechia salebrosa*, slide MHNG ENTO 6029. (97) *Mesophleps adustipennis*, slide MHNG ENTO 6018.




FIGS 98–100

Female genitalia of Galapagos Gelechiinae, Pexicopiinae, and Dichomeridinae. (98) *Untomia lunatella*, slide MHNG ENTO 6035. (99) *Sitotroga cerealella*, slide MHNG ENTO 6021. (100) *Dichomeris acuminatus*, slide MHNG ENTO 4931.




Figs 101–102

Female genitalia of Galapagos unidentified Gelechiinae. (101) Gnorimoschemini sp. A, slide MHNG ENTO 4930. (102) Gnorimoschemini sp. B, slide MHNG ENTO 6014.

## CONCLUSIONS

In the present state of knowledge of the whole Galapagos Lepidoptera fauna, the Gelechiidae, with 22 species, plus an additional two species untreated taxonomically here, represent the third most diverse family following the Noctuidae and Pyralidae (sensu lato). Undoubtedly there are more species present, some of them almost certainly endemic. In addition, some widespread species like *Phthorimaea operculella* (Zeller, 1873), a major pest of potato, tobacco, and a variety of other plants, will probably make their way to the archipelago eventually, given the high rate of exchange of goods and people with the continent. All in all, there is still much to learn from this mega-diverse group of moths in the Galapagos, especially regarding the host plant associations of the species.

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## REFERENCES

Beccaloni, G. W., Scoble, M. J., Robinson, G. S. & B. Pitkin (Editors). 2003. The Global Lepidoptera Names Index (LepIndex). World Wide Web electronic publication. http://www.nhm.ac.uk/entomology/lepindex. *The Natural History Museum, London*. [Last checked March 31, 2010]

Becker, V. O. 1984. Gelechiidae, pp. 44–53 *In*: Heppner, J. B. (ed.), Atlas of Neotropical Lepidoptera, Checklist, Part 1, Micropterigoidea – Immoidea. *Dr W. Junk Publishers, The Hague*.

Bradley, J. D. & Povolný, D. 1965. The identity of the pepper flower-bud moth. *Bulletin of entomological Research* 56: 57–63.

Braun, A. F. 1930. Notes on new species of Microlepidoptera from the Mineral Springs Region of Adams County, Ohio. *Transactions of the American Entomological Society* 56: 1–17.

Busck, A. 1901. A new Canadian Tineid. *Canadian Entomologist* 33: 14–16.

Busck, A. 1906. Tineid moths from Southern Texas, with descriptions of new species. *Proceedings of the United States National Museum* 30: 721–736.

Busck, A. 1910. A new Tineid from Trinidad. *Bulletin of the Department of Agriculture of Trinidad and Tobago* 9: 243–246.

Busck, A. 1939. Restriction of the genus *Gelechia* (Lepidoptera: Gelechiidae), with descriptions of new genera. *Proceedings of the United States National Museum* 86, no. 3064: 563–593, pls 58–71.

BUTLER, A. G. 1881. On a collection of nocturnal Lepidoptera from the Hawaiian Islands. *Annals and Magazine of Natural History* (5) 7: 392–408.

CAUSTON, C. E., PECK, S. B., SINCLAIR, B. J., ROQUE-ALBELO, L., HODGSON, C. J. & LANDRY, B. 2006. Alien insects: Threats and implications for conservation of Galápagos Islands. *Annals of the Entomological Society of America* 99 (1): 121–143.

CHAMBERS, V. T. 1872. Micro-Lepidoptera. *Canadian Entomologist* 4: 191–195.

CHAMBERS, V. T. 1875. Tineina from Texas. *Canadian Entomologist* 7: 92–95.

CLARKE, J. F. G. 1965. Microlepidoptera of Juan Fernandez Islands. *Proceedings of the United States National Museum* 117 (3508): 1–105.

CLARKE, J. F. G. 1969a. Catalogue of the type specimens of Microlepidoptera in the British Museum (Natural History) described by Edward Meyrick. Volume VI. *Trustees of the British Museum (Natural History). London*, 537 pp.

CLARKE, J. F. G. 1969b. Catalogue of the type specimens of Microlepidoptera in the British Museum (Natural History) described by Edward Meyrick. Volume VII. *Trustees of the British Museum (Natural History). London*, 531 pp.

CLARKE, J. F. G. 1986. Pyralidae and microlepidoptera of the Marquesas Archipelago. *Smithsonian Contributions to Zoology* 416: iii + 485 pp.

CLEMENS, B. 1860. Contributions to American Lepidopterology. No. 4. *Proceedings of the Academy of Natural Sciences of Philadelphia* 12: 156–174.

ELSNER, G., HUEMER, P. & TOKAR, Z. 1999. Die Palpenmotten Mitteleuropas (Lepidoptera, Gelechiidae). *F. Slamka, Bratislava*. 208 pp.

FORBES, W. T. M. 1930. Scientific Survey of Porto Rico and the Virgin Islands. Vol. 12, part 1. Heterocera or moths (excepting the Noctuidae, Geometridae and Pyralidae). *New York Academy of Sciences*. 171 pp., 2 pls.

FORBES, W. T. M. 1931. Supplementary report on the Heterocera or Moths of Porto Rico. The *Journal of the Department of Agriculture of Porto Rico*, 15 (4): 339–393, pls 42–47.

HEINEMANN, H. V. 1870. Die Schmetterlinge Deutschlands und der Schweiz. Zweite Abteilung. Kleinschmetterlinge. Band 2: Die Motten und Federmotten. *C. A. Schwetschke & Sohn, Braunschweig*. 388 pp.

HEPPNER, J. B. 1991. Faunal regions and the diversity of Lepidoptera. *Tropical Lepidoptera* 2 (suppl. 1): 1–85.

HODGES, R. W. 1986. Gelechioidea, Gelechiidae (part), Dichomeridinae. *In*: DOMINICK, R. B., *et al.* (eds). The Moths of America North of Mexico, fasc. 7.1. *Wedge Entomological Research Foundation, Washington, D.C.*, 195 + xiii pp.

HODGES, R. W. 1998. The Gelechioidea. Pp. 131–158 In: Kristensen, N. P. (Ed.), Handbook of zoology, vol. IV, Part 35, Lepidoptera, moth and butterflies, vol. 1, Evolution, systematics, and biogeography. *W. de Gruyter, Berlin, New York*.

HODGES, R. W. 1999. Gelechioidea, Gelechiidae (part), Gelechiinae (part-*Chionodes*). *In*: DOMINICK, R. B., *et al.* (eds). The Moths of America North of Mexico, fasc. 7.6. *Wedge Entomological Research Foundation, Washington, D.C.*, 339 pp.

HODGES, R. W. & V. O. BECKER 1990. Nomenclature of some Neotropical Gelechiidae (Lepidoptera). *Proceedings of the Entomological Society of Washington* 92: 76–85.

HÜBNER, J. 1816–1826. Verzeichniss bekannter Schmettlinge [sic]. Augsburg. 431 + 72 pp. (index).

HÜBNER, J. 1806–1832. Sammlung exotischer Schmetterlinge, vol. 1. [Augsburg]. [title page], [1]–[36], (index systematicus) [1]–[4], pls [1]–[213].

KARSHOLT, O. & RIEDL, T. 1996. Gelechiidae (part). Pp. 103–122 *In*: KARSHOLT, O. & J. RAZOWSKI (Eds), The Lepidoptera of Europe, a distributional checklist. *Apollo Books, Stenstrup*.

KARSHOLT, O. & SATTLER, K. 1998. A new brachypterous *Ephysteris* Meyrick from the island of Madeira (Lepidoptera, Gelechiidae). *Entomologist's Gazette* 49: 35–47.

KIEFFER, J. J. & JÖRGENSEN, P. 1910. Gallen und Gallentiere aus Argentinien. *Zentralblatt für Bakteriologie Parasitenkunde, Infektionskrankheiten und Hygiene* 27: 362–444.

KRISTENSEN, N. P. 2003. 4. Skeleton and muscles: adults. Pp. 39–131 *In*: Kristensen, N. P. (Ed.), Handbook of zoology, vol. IV, Part 36, Lepidoptera, moth and butterflies, vol. 2, Morphology, physiology, and development. *W. de Gruyter, Berlin, New York*.

LANDRY, B. 2002. *Galagete*, a new genus of Autostichidae representing the first case of an extensive radiation of endemic Lepidoptera in the Galápagos Islands. *Revue suisse de zoologie* 109: 813–868.

LANDRY, B. 2006. The Gracillariidae (Lepidoptera, Gracillarioidea) of the Galapagos Islands, Ecuador, with notes on some of their relatives. *Revue suisse de zoologie* 113: 437–485.

LAWESSON, J. E., ADSERSEN, H. & BENTLEY, P. 1987. An updated and annotated check list of the vascular plants of the Galapagos Islands. *Report of the Botanical Institute, University of Aarhus* No. 16. 74 pp.

LEE, S. & BROWN, R. L. 2008. Revision of Holarctic Teleiodini (Lepidoptera: Gelechiidae). *Zootaxa* 1818: 1–55.

LEE, S., HODGES, R. W. & BROWN, R. L. 2009. Checklist of Gelechiidae (Lepidoptera) in America North of Mexico. *Zootaxa* 2231: 1–39.

LI, H. & BIDZILYA, O. 2008. A review of the genus *Ephysteris* Meyrick, 1980 from China, with descriptions of two new species (Lepidoptera: Gelechiidae). *Zootaxa* 1733: 45–56.

LINSLEY, E. G. 1977. Insects of the Galápagos (Supplement). *Occasional papers of the California Academy of Sciences*. No. 125. 50 pp.

LINSLEY, E. G. & USINGER, R. L. 1966. Insects of the Galápagos Islands. *Proceedings of the California Academy of Sciences, 4th series*. 33(7): 113–196.

MCMULLEN, C. K. 1999. Flowering plants of the Galápagos. *Comstock Publishing Associates, Ithaca and London*. xiv + 370 pp.

MEYRICK, E. 1902. A new genus of Gelechiadae. *Entomologist's Monthly Magazine* 38: 103–104.

MEYRICK, E. 1904. Descriptions of Australian Microlepidoptera. 1. Gelechiadae. *Proceedings of the Linnean Society of New South Wales* 29: 255–441.

MEYRICK, E. 1908. Descriptions of African Micro-Lepidoptera. *Proceedings of the Zoological Society of London*, 1908: 716–756.

MEYRICK, E. 1917. Descriptions of South American Micro-Lepidoptera. *Transactions of the Entomological Society of London*, 1917: 1–52.

MEYRICK, E. 1918. Exotic Microlepidoptera 2: 129–160.

MEYRICK, E. 1921. Exotic Microlepidoptera 2: 417–448.

MEYRICK, E. 1922. Descriptions of South American Micro-Lepidoptera. *Transactions of the Entomological Society of London*, 1922: 65–116.

MEYRICK, E. 1925. Lepidoptera Heterocera, fam. Gelechiadae [sic]. Fasc. 183 *In*: Wytsman, P. (Ed.) Genera Insectorum. *Louis Desmet-Verteneuil, Bruxelles*. 290 pp, 5 pls.

MEYRICK, E. 1926. On micro-lepidoptera from the Galapagos Islands and Rapa. *Transactions of the Entomological Society of London* 74: 269–278.

MEYRICK, E. 1927. Micro-Lepidoptera. In: Insects of Samoa. Lepidoptera 3(2): 65–116. *British Museum (Natural History), London*.

MEYRICK, E. 1931. Micro-Lepidoptera from South Chile and Argentina. *Anales del Museo Nacional de Historia natural Bernardino Rivadavia, Buenos Aires* 36: 377–415.

OLIVIER, G.-A. 1789. Encyclopédie méthodique. Histoire naturelle. Vol. 4. Insectes. *Panckoucke, Paris*. 331 pp.

PECK, S. B. 2001. Smaller orders of insects of the Galapagos Islands, Ecuador: Evolution, ecology, and diversity. *NRC Research Press, Ottawa*. xii + 278 pp.

POVOLNÝ, D. 1964. Gnorimoschemini Trib. nov. – Eine neue Tribus der Familie Gelechiidae nebst Bemerkungen zu ihrer Taxonomie. *Casopis Ceskoslovenské Spolecnosti entomologické* 61: 330–359, figs 1–69, col. pls 1–19.

POVOLNÝ, D. 1966. A type revision of some Old-World species of the tribe Gnorimoschemini with a special regard to pests (Lepidoptera). *Acta entomologica bohemoslovaca* 63: 128–148.

POVOLNÝ, D. 1967. Genitalia of some Nearctic and Neotropic members of the tribe Gnorimoschemini (Lepidoptera, Gelechiidae). *Acta entomologica Musei Nationalis Pragae* 37: 51–127.

POVOLNÝ, D. 1987. Gnorimoschemini of southern South America III: the scrobipalpuloid genera (Insecta, Lepidoptera, Gelechiidae). *Steenstrupia* 13: 1–91.

POVOLNÝ, D. 1989. Gnorimoschemini of southern South America IV: the genera *Symmetrischema* and *Phthorimaea* (Lepidoptera, Gelechiidae). *Steenstrupia* 15: 57–104.

POVOLNÝ, D. 1990. Gnorimoschemini of Peru and Bolivia (Lepidoptera, Gelechiidae). *Steenstrupia* 16: 153–223.

POVOLNÝ, D. 1994. Gnorimoschemini of southern South America VI. Identification keys, checklist of Neotropical taxa and general considerations (Insecta, Lepidoptera, Gelechiidae). *Steenstrupia* 20: 1–42.

POVOLNÝ, D. 1999. Two indigenous Nearctic species of the genus *Microcraspedus* Janse, 1958 (Lepidoptera: Gelechiidae). *SHILAP Revista de lepidopterologia* 27: 413–417.

POVOLNÝ, D. 2002. Iconographia tribus Gnorimoschemini (Lepidoptera, Gelechiidae) Regionis Palaearcticae. *Slamka, Bratislava*. 110 pp., 16 colour pls, 87 b/w pls.

POWELL, J. A. & D. POVOLNÝ 2001. Gnorimoschemine moths of coastal dune and scrub habitats in California (Lepidoptera: Gelechiidae). *Holarctic Lepidoptera* 8, Suppl. 1: 1–53.

ROBINSON, G. S., ACKERY, P. R., KITCHING, I. J., BECCALONI, G. W. & HERNÁNDEZ, L. M. 2007. HOSTS - a Database of the World's Lepidopteran Hostplants. http://www.nhm.ac.uk/-research-curation/projects/hostplants/. *The Natural History Museum, London*. [Last checked March 23, 2010]

ROQUE-ALBELO, L. 2003. Population decline of Galapagos endemic Lepidoptera on Volcán Alcedo (Isabela Island, Galapagos Islands, Ecuador): An effect of the introduction of the cottony cushion scale? *Bulletin de l'Institut royal des sciences naturelles de Belgique, Entomologie* 73: 177–180.

SCHAUS, W. 1923. Galapagos Heterocera with descriptions of new species. *Zoologica* 5(2): 22–48.

SCHMITZ, P. & LANDRY, B. 2007. Two new species of *Chionodes* Hübner from Ecuador, with a summary of known Galapagos records of Gelechiidae (Lepidoptera). *Revue suisse de zoologie* 114: 175–184.

STAINTON, H. T. 1867. The Tineina of Syria and Asia Minor. *Van Voorst, London*. 84 pp.

STAUDINGER, O. 1876. Beiträge zur Lepidopteren-Fauna Sicilien's. *Entomologische Zeitung, Stettin* 37: 138–150.

VARI, L., KROON, D. M. & KRÜGER, M. 2002. Classification and checklist of the species of Lepidoptera recorded in Southern Africa. *Simple Solutions, Chatswood, Australia*. xxi + 384 pages.

WALSINGHAM, T. DE G. 1891. African Micro-Lepidoptera. *Transactions of the Entomological Society of London*, 1891: 63–132, pls 3–7.

WALSINGHAM, T. DE G. 1897. Revision of West-Indian Micro-Lepidoptera, with descriptions of new species. *Proceedings of the Zoological Society of London*, 1897: 54–183.

WALSINGHAM, T. DE G. 1909–1915. Biologia Centrali-Americana, Insecta Lepidoptera-Heterocera Vol. 4, Tineina, Pterophorina, Orneodina, and Pyralidina and Hepialina (part). *London*. xii + 482 pp., 10 pls.

ZELLER, P. C. 1873. Beiträge zur Kenntniss der nordamericanischen Nachtfalter, besonders der Microlepidopteren. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien* 23: 201–334, pls 3, 4.

ZELLER, P. C. 1877. Exotische Microlepidoptera. *Horae Societatis entomologicae Rossicae* 13: 1–491, pls 1–6.

ZIMMERMAN, E. C. 1978. Microlepidoptera, Parts 1 and 2. Insects of Hawaii, Vol. 9. *University of Hawaii Press, Honolulu*. xviii + 1903 pp. + 8 colour pls.

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# The Psilidae (Diptera, Acalyptrata) of Switzerland, with description of two new species from Central Europe

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**The Psilidae (Diptera, Acalyptrata) of Switzerland, with description of two new species from Central Europe.** - The family Psilidae is reviewed for Switzerland and data are listed for all species currently known from this country. *Chamaepsila sardoa* (Rondani) and *Ch. unilineata* (Zetterstedt) are recorded for the first time from Switzerland. *Psila* (s. str.) *helvetica* sp. n. (Switzerland) and *Chamaepsila confusa* sp. n. (France, Switzerland) are described and illustrated. Keys for the European species of *Psila* s. str. Meigen and the *Chamaepsila pallida* group are provided. A summary of diagnostic characters of the genera of *Psila* s. lat. is given. An updated checklist of the 36 Swiss species is presented.

**Keywords:** Psilidae - Switzerland - new species - keys - checklist.

## INTRODUCTION

The Psilidae are a small family of acalyptrate Diptera with 335 species described from all biogeographical regions. Most species occur in the Holarctic Region with 153 species currently known from the Palaearctic Region. They are considered to be monophyletic with some well-supported apomorphic character states: wing venation peculiar (the costa has a break at the distal end of the subcosta which is reaching the costa as a fold; the distal margin of cell cup (anal cell, posterior cubital cell) is closed by a straight vein CuA2) and chaetotaxy reduced (0-1 notopleural setae; acrostichal setulae usually not differentiated; pleuron bare or covered with setulae, but without setae).

Traditionally, the family is divided into two subfamilies, the Chylizinae and the Psilinae. The Chylizinae (116 species worldwide, particularly numerous in the Afrotropical and Oriental Regions, 22 species in the Palaearctic Region) are probably plesiomorphic whereas the Psilinae (216 species described mainly from the Holarctic Region, few species in the Afrotropical and Oriental Regions, unknown in the Neotropics) are usually considered to be a monophyletic group. The Psilinae consist mainly of slender species ranging from 3 mm (often in *Psila* s. lat.) to 13 mm (some *Loxocera* spp.). They have usually a triangular head with a receding face in profile.

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Their parafacialia lacks silvery white microtrichia. The male terminalia are characterized by well-developed parameres and by the absence of a surstylus. The Chylizinae are more stumpy flies and differ from the Psilinae by the developed postcoxal bridge and the presence of a surstylus in the male. Their parafacialia is silvery microtrichose. McAlpine (1997) considered this last character as groundplan condition of Diopsoidea (Diopsidae and Syringogastridae), but it is also present in some species of other families (Megamerinidae, Strongylophthalmyiidae, Tanypezidae).

Recently, Shatalkin (2001) proposed a third subfamily, the Belobackenbardiinae for three species of *Belobackenbardia* Shatalkin from South Africa. They are externally similar to primitive species of *Psila* s. lat., but their parafacialia is silvery microtrichose. Also, their male terminalia do not have any resemblance with those of other Psilidae and related families. It is possible that their similarity with *Psila* s. lat. is due to convergence.

The known larvae of Psilidae are phytophagous (Ferrar, 1987; Iwasa, 1998). They are tunneling in stems, rootstocks and bulbs, or live under the bark of thin twigs of trees. The larvae of the common European species *Chyliza leptogaster* (Panzer) may cause phloem necroses in deciduous trees (Dengler, 1997). Those of *Chyliza annulipes* Macquart have been recorded from conifers, in particular from resinous wounds (Lyneborg, 1987). *Chyliza vittata* has been reared from mines in stems and roots of Orchidaceae (de Meijere, 1940; Petit, 1982) whereas the larvae of the externally similar Chinese *Chyliza bambusae* Yang & Wang develop in roots of bamboo (Yang & Wang, 1988). The Nearctic *Chyliza leguminicola* Melander is feeding from the lower part of *Lupinus polyphyllus* (Melander, 1920). Species of *Loxocera* and some *Psila* s. lat. are often found in marshland where their larvae are developing in stems of Cyperaceae (*Carex*) or Juncaceae (*Juncus*).

Only few species of the family are of economic importance. The larvae of the carrot fly, *Chamaepsila rosae* (Fabricius), may cause important damage in edible roots of carrots and other umbelliferous crops (celery [= *Apium graveolens*], parsley [= *Petroselinum hortense*], parsnip [= *Pastinaca sativa*]) and some cruciferous species (cabbage [= *Brassica* sp.], turnip [= *Brassica rapa*]). Another pest species is *Chamaepsila nigricornis* (Meigen) whose larvae feed in roots of ornamental plants.

## REVIEW OF THE FAUNISTIC RESEARCH IN SWITZERLAND

Switzerland is a small country in Central Europe but of a remarkable diversity with currently almost 7'000 species of Diptera recorded (Merz *et al.*, 2007). This may be explained by the presence of species which are widely distributed in temperate Central Europe living in various types of grassland from swamps to rather dry meadows and in deciduous and evergreen forests. In addition, a notable influence of the Mediterranean fauna may be recorded in Southern Switzerland and the region of Geneva. The dry Central Alpine valleys are famous for some steppose, East European species. Finally, numerous Scandinavian or boreal species were found in Subalpine and Alpine Regions of the Alps and the Jura chain.

The Psilidae of Switzerland have never been studied. The only historical list with six reliable records was published by Ringdahl (1957). Later, Merz (1998) established the Swiss checklist with 31 species based on about 600 specimens housed

in the 10 most important public collections of Switzerland. However, no data with precise information (localities, dates of collecting) were provided. One species, *Loxocera maculata*, was later added by Merz *et al*. (2002).

The motivation of the present paper is threefold. First, the knowledge of the Swiss fauna is reviewed with inclusion of distributional data for all species and a revised checklist is provided here in the appendix. Second, the occasion is taken to describe two species new to science which were discovered during the preparation of the paper. And finally, updated keys are given for some taxonomically difficult groups in the light of new results which were obtained by the study of the present specimens.

## MATERIAL AND METHODS

This study is based on about 330 specimens which were almost exclusively collected in Switzerland (CH) and which are deposited in the collection of the Natural History Museum Geneva (MHNG). Few duplicate specimens are also kept in the Zoological Museum of the Moscow State University (ZMUM). In addition, the type series of one species, *Scatophaga pallida* Fallén, deposited in the Swedish Museum of Natural History (NRS) was examined.

The responsabilities are distributed as follows: The first author identified at least one specimen of each species. He prepared a draft version of the manuscript with the descriptions and illustrations of the species and with the elaboration of the new facts and keys arising from the study of the specimens. The second author identified further specimens of almost all species and he prepared an updated version of the manuscript.

For identification, the following keys and revisions were used: Hennig (1941), Collin (1944), Lyneborg (1964), Shatalkin (1986), Wang (1988), Greve & Midtgaard (1989), Shtakel'berg (1989), Carles-Tolrá (1993a), van der Goot & van Veen (1996), Iwasa (1998), and Greve & Skartveit (2000). Data about the distribution of the species in Europe is partly taken from Pape (2007).

Terminology and nomenclature in the systematic part follows basically Iwasa (1998) and Merz & Haenni (2000). The genera are arranged in a phylogenetic order and the species alphabetically within the genera. The specimens are listed in alphabetical order for cantons.

## SYSTEMATIC PART

### Subfamily Chylizinae

This subfamily includes the single genus *Chyliza*. It is characterized by the following unique combination of characters: anatergal area of laterotergite enlarged, callus-like; occiput concave; face nearly perpendicular, not retreating; head not triangular in profile; usually three (pairs of) scutellar setae; postcoxal bridge developed; anal cell (posterior cubital cell, cup) shorter than 2nd basal cell.

### Genus ***Chyliza*** Fallén, 1820

Type species: *Musca leptogaster* Panzer, 1798, by subsequent designation of Westwood, 1840: 146.

COMMENTS: In Europe, five species are recognized (Hennig, 1941; Soós, 1984) which all occur in Switzerland. "*Chyliza*" *gracilis* Loew, 1854, is considered here to belong to the subfamily Psilinae (see below).

***Chyliza annulipes*** Macquart, 1835

MATERIAL SWITZERLAND: 1♂, GE, Corsier-Port, vitre véranda, 27-31 V 2005, leg. C. Besuchet. – 1♂, ZH, 400 m, Embrach-Haumüli, 9 V 1998, leg. B. Merz. – 1♂, 1♀, ZH, 460 m, Zürich-Ziegelhütte, 10 V 1997, leg. B. Merz.

***Chyliza extenuata*** (Rossi, 1790)

MATERIAL SWITZERLAND: 1♂, 1♀, FR, 460-650 m, Mt. Vully, Bas Vully, 6 VI 2003, leg. B. Merz & F. Amiet. – 1♂, GE, 510 m, Bernex, Signal, 24 V 2002, leg. B. Merz. – 1♂, GE, Corsier-Port, vitre véranda, 1-31 V 2009, C. Besuchet.

COMMENTS: Larvae develop in roots of broomrapes (*Orobanche* spp.). Outside of Europe this species is recorded from Central Asia.

***Chyliza leptogaster*** (Panzer, 1798)

MATERIAL SWITZERLAND: 1♂, GE, Corsier-Port, vitre véranda, 20-30 VI 2008, leg. C. Besuchet. – 2♀, GE, 350 m, Chancy, La Laire, 1 VII 2001, leg. B. Merz. – 1♀, GE, 500 m, Bernex-Signal, 17 VI 2009, B. Merz. – 1♂, GR, 980 m, Andeer-Clugin, 17 V 1994, leg. B. Merz. – 1♀, SG, 610 m, Wattwil, 11 VII 1997, leg. B. Merz. – 1♂, TI, 350 m, Biasco-Loderio, 7180/1375, 16 V 2006, leg. B. Merz. – 1♀, TI, 600-1100 m, Monte San Giorgio, 717180/085700, 5 VII 2001, leg. B. Merz. – 1♀, VS, 750 m, Branson/Follatères, 9 VI 2004, leg. B. Merz & J.-P. Haenni. – 1♀, VS, 700-770 m, Raron-Heidnischbiel, 26 V 1999, leg. B. Merz. – 1♀, VS, 750 m, Raron-Heidnischbiel, 3 VII 2003, leg. Merz, Smit & van Det. – 1♂, VS, 625 m, Leuk-Platten, 8 VI 2001, leg. B. Merz & B. Landry. – 1♀, ZH, 650 m, Zürich-Zürichberg, 26 VII 1995, M.Fal [Malaise trap], S.Ungricht.

***Chyliza nova*** Collin, 1944

MATERIAL SWITZERLAND: 1♀, GE, 440 m, Bernex-Saule, 14 VI 2009, B. Merz. – 1♀, GE, 440 m, Bernex-Saule, 19 VI 2008, leg. B. Merz. – 1♀, GE, 440 m, Bernex-Signal, 25 VI 2009, B. Merz. – 1♂, GE, Corsier-Port, vitre véranda, 1-30 VI 2004, leg. C. Besuchet. – 1♀, VD, Bonvillars, La Coudre, 10 VII 1991, leg. J. Steffen. – 1♂, ZH, 450 m, Zürich-Waldgarten, 24 V 1996, leg. B. Merz. – 1♂, ZH, 460 m, Zürich-Ziegelhütte, 29 VI 1997, leg. B. Merz.

***Chyliza vittata*** Meigen, 1826

MATERIAL SWITZERLAND: 1♀, BE, 650-950 m, Mt. Raimeux, Corcelles, 2 VI 2003, leg. B. Merz. – 1♂, GE, 350 m, Cartigny, Moulin de Vert, 24 V 1999, leg. Merz & Müller.

## SUBFAMILY PSILINAE

### Tribe Loxocerini

COMMENTS: Traditionally, this tribe includes *Psila*-like flies which are characterized by a long postpedicel which is longer than the head, and by a pad of short setulae which are often present near the ventral tip of the hind femur. In Europe, this tribe is represented by the genus *Loxocera* s. lat. (see below). Shatalkin (1998) proposed a new subgenus, *Asiopsila* Shatalkin, for Oriental species of small size (3.5-5 mm) without the pad of short setulae on the hind femur but with a whitish spot in the upper part of the katepisternum. Later, Buck & Marshall (2006b) transferred this subgenus in the tribe Psilini where it is considered to be a subgenus of *Psila* s. str. Their

conclusion seems to be justified. However, it should be noted that the structure of the male terminalia with the reduced parameres in *Asiopsila* differs strongly from the superficially similar external morphology in other taxa of the Psilini. In this respect they resemble species of *Loxocera* s. lat. Following this conclusion *Loxocera glandicula* Iwasa, 1993, which is close to *L. aristata*, is the only Oriental species of *Loxocera* s. str.

Hennig (1941) and Steyskal (1987) treated *Platystyla* Macquart, 1835, as a subgenus of *Loxocera*. Species of *Platystyla* are characterized by extremely long antennal segments and a strongly thickened and flattened arista which is inserted near the middle of the postpedicel or even more apically (the part distal of the insertion of the arista on the postpedicel is 1.0-1.3 times as long as the part basal of it). Earlier, Frey (1925) treated *Loxocera* and *Platystyla* as distinct genera and he proposed the new subgenus *Imantimyia* Frey within *Loxocera* for *Loxocera albiseta* (Schrank) and morphologically similar species (*L. sylvatica* and *L. fulviventris*). Recently, Buck & Marshall (2006b) proposed a new classification based on a phylogenetic study of Nearctic and Palaearctic Loxocerini, in particular of the egg structure and the male terminalia. They concluded that *Loxocera* sensu Frey (1925) or Hennig (1941) is paraphyletic and they suggested that *Imantimyia* is the sister-group of (*Loxocera* s. str. + *Platystyla*). As a consequence of this phylogenetic study they treat *Imantimyia* and *Platystyla* as subgenera of *Loxocera*. However, based on its morphological peculiarities with the strongly modified antennae it is difficult to accept the proposition that *Platystyla* with its 5 Oriental and Palaearctic species (Frey, 1955) should be considered as subgenus of *Loxocera*. In order to preserve the new phylogenetic hypothesis of Buck & Marshall (2006b) the following concept is proposed here: *Imantimyia* is treated as a separate genus, whereas *Platystyla* is placed as subgenus within *Loxocera*. Following this proposition it should be noted that *Tropeopsila* Shatalkin, 1983, described for two East Palaearctic species and which was not studied by Buck & Marshall (2006b), is a subgenus of *Loxocera*.

Species of *Loxocera* and *Imantimyia* develop in stalks of sedges (de Meijere, 1941; Chandler, 1975; Ferrar, 1987). The tribe contains currently 54 species; 18 species are known from the Palaearctic Region. All 7 European species (Pape, 2007) occur in Switzerland.

Genus ***Loxocera*** Meigen, 1803

Type species: *Musca aristata* Panzer, 1801, by monotypy.

Comments: In the current interpretation, *Loxocera* is a well characterized genus. It differs from the other genus of the tribe, *Imantimyia*, by the following characters (see also Buck & Marshall, 2006b): frons with a pair of desclerotized velvety vittae; lunule semicircular between antennal bases and anterior margin of frons, crest-like (usually hidden in *Imantimyia*); alula bare at least medially; male pregenital sclerite large and setulose (small and bare in *Imantimyia*); female cerci not fused with tergite 10 (fused in *Imantimyia*).

According to the present concept, the genus contains besides the nominal subgenus also the two subgenera *Platystyla* Macquart and *Tropeopsila* Shatalkin. In Europe, two species of *Loxocera* s. str. and one species of *Platystyla* are known, all occurring also in Switzerland.

Subgenus ***Loxocera*** Meigen, 1803

***Loxocera* (s. str.) *aristata*** (Panzer, 1801)

MATERIAL SWITZERLAND: 1♀, BE, 995 m, Tramelan, La Tourbière, 4 VI 2003, Merz, Haenni & Rapp. – 1♀, GE, 400 m, Bernex, Chante-Merle, 1 VI 2009, leg. B. Merz. – 1♀, GE, 420 m, Bernex, Bois des Mouilles, 19 VIII 2006, leg. B. Merz. – 1♀, GE, Corsier-Port, vitre véranda. 1-15 IX 2008, C. Besuchet. – 1♂, GE, Corsier-Port, vitre véranda, 27-31 V 2005, leg. C. Besuchet. – 1♀, GL, 1500 m, Pragelpass, 5 VIII 1991, leg. Bächli, Beuk, Merz. – 1♀, JU, 1020 m, Les Breuleux, La Tourbière, 4 VI 2003, leg. Merz, Haenni & Rapp. – 1♀, JU, 1000 m, La Chaux-des-Breuleux, La Tourbière, 28 VI 2003, leg. B. Merz. – 1♀, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 1♀, VS, 1700-1900 m, Morgins-En Tey, 22 VI 2003, leg. B. Merz.

***Loxocera* (s. str.) *maculata*** Rondani, 1876 Figs P1-P2

MATERIAL SWITZERLAND: 4♂, 5♀, VS, 2000 m, Simplon/Hospiz, 645450/121680, 4 VII 2001, leg. B. Merz.

COMMENTS: The status of this species is subject to different interpretations. Some authors synonymized *L. maculata* with *L. aristata*, for instance Hennig (1941) and Soós (1982) who studied the types in the collection of Rondani. Later, however, Soós (1984) treated *L. maculata* as a good species with *L. atriceps* Bigot, 1886, and *L. yerburyi* Austen, 1899, as synonyms. This concept was adopted by Schacht (1996) for Bavaria, van der Goot & van Veen (1996) for the Netherlands and Merz *et al.* (2002) for Switzerland. On the other hand, Barták & Carles-Tolrá (2006) in the Catalogue of Diptera of Czech and Slovak Republics listed *L. maculata* as subspecies of *L. aristata*.

*L. atriceps*, considered to be a synonym of *L. maculata* by Soós (1984), is now believed to be a variety of *L. aristata* differing only in its colouration.

The Swiss specimens of *L. maculata* differ from those of other countries. They are characterized by a rather short postpedicel which is shorter than the length of the frons (measured from the posterior ocelli to the lunule), by a long arista which is longer than the postpedicel, and by an entirely black thorax (Figs P1, P2).

In external characters *L. maculata* differs from *L. aristata* by its almost black thorax including the scutellum. On the other hand, no clear differences in the structure of the male terminalia have yet been found. Therefore, additional specimens from various localities are necessary in order to clarify the taxonomy of the two taxa. For the time being they are treated as distinct species.

Subgenus ***Platystyla*** Macquart, 1835

TYPE SPECIES: *Loxocera hoffmannseggi* Meigen, 1826, by monotypy.

COMMENTS: In the current interpretation the subgenus contains five species, four of which are recorded from the East Palaearctic Region (Russian Far East, Japan, China). One species occurs in Europe.

***Loxocera (Platystyla) hoffmannseggi*** Meigen, 1826

MATERIAL SWITZERLAND: 1♂. Bern, Kirchenfeld, 19 VIII 1924, leg. Th. Steck. – 1♂, ZH, 410 m, Embrach-Haumüli, 20 VIII 1997, leg. B. Merz.

Genus ***Imantimyia*** Frey, 1925

TYPE SPECIES: *Nemotelus albiseta* Schrank, 1803, by original designation.

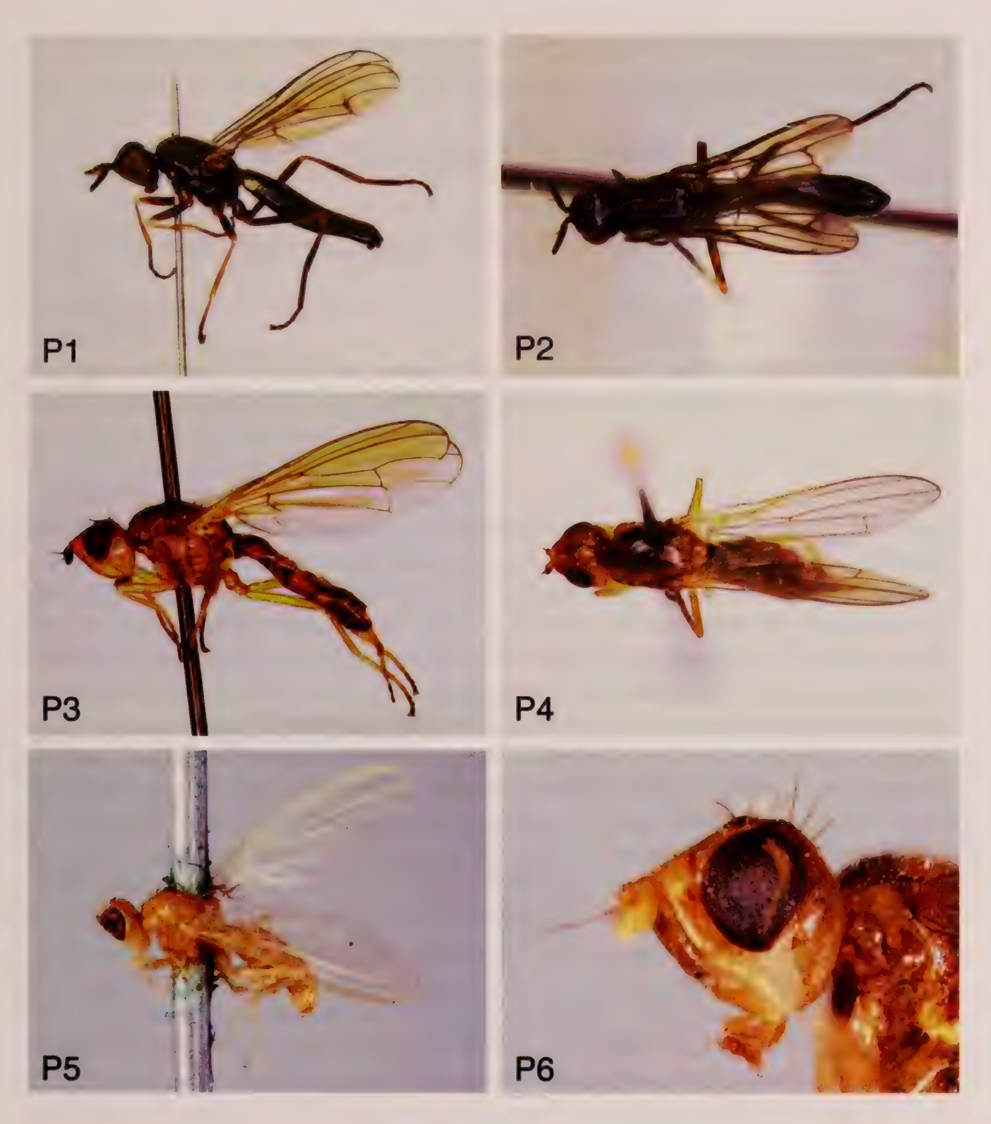



PLATE 1-6

Habitus and details of Psilidae. (P1, P2) *Loxocera maculata* Rondani, habitus lateral and dorsal (CH, VS, 2000 m, Simplon/Hospiz, 645450/121680, 4 VII 2001). (P3, P4) *Psila helvetica* sp. n. (holotype, CH, VS, 650 m, Leuk-Pfynwald, 23 IX 1992). (P5) *Chamaepsila pallida* (Fallén) (male syntype, probably from Sweden, Esperöd, NRS). (P6) head of *Ch. pallida* (female syntype, probably from Sweden, Esperöd, NRS).

COMMENTS: The European fauna contains four species which are all known from Switzerland.

***Imantimyia albiseta*** (Schrank, 1803)

MATERIAL SWITZERLAND: 4♀, GE, 420 m, Bernex, Bois des Mouilles, 19 VIII 2006, leg. B. Merz. – 1♀, SG, 910 m, Unterwasser, 15 VIII 1997, leg. B. Merz. – 1♂, ZH, 450 m, Zürich-Allmend, 10 IX 1996, leg. B. Merz.

***Imantimyia fulviventris*** (Meigen, 1826)

MATERIAL SWITZERLAND: 1♂, 1♀, ZH, 515 m, Illnau-Wildert, 5 VIII 1997, leg. B. Merz.

COMMENTS: Both specimens were collected at light in a peat-bog.

***Imantimyia nigrifrons*** (Macquart, 1835)

MATERIAL SWITZERLAND: 1♂, GE, 360 m, Dardagny, Le Moulin, 8 VII 2002, leg. B. Merz.

***Imantimyia sylvatica*** (Meigen, 1826)

MATERIAL SWITZERLAND: 1♂, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 1♂, ZH, 410 m, Glattfelden-Bahnhof, 15 V 1993, leg. B. Merz. – 1♀, ZH, 620-670 m, Zürich-Zürichberg, 11 V 1995, leg. B. Merz.

Tribe Psilini

COMMENTS: This is the most diverse tribe of the family in Europe with 34 described species. It includes notably *Psila* Meigen, 1803, with its confusing history. It was described for species which could not be placed elsewhere and which exhibit a series of negative characters. For instance, the type-species, *Musca fimetaria* Linnaeus, is characterized by numerous reductions in its chaetotaxy. With increasing knowledge of the group, also from other biogeographical areas than the Western Palaearctic Region, numerous generic or suprageneric taxa were proposed which were later often synonymized or given only subgeneric status within *Psila* Meigen. Such a phenetic approach was justified before the development of the principles of phylogeny. In all cases the status of several species remained unresolved and resulted in residual taxa. Hendel (1917) described the genus *Chamaepsila* to accommodate species of *Psila* with postocellar setae developed, and thus differing from *Psila* s. str. where they are absent (e. g., the type-species *M. fimetaria*). Few years later, Frey (1925) proposed the new genus *Oxypsila* for *Psila abdominalis* Schummel which lacks dorsocentral and post-ocellar setae. The remaining species of *Psila* s. str. are thus a morphologically distinct group which may be regarded as a specialized offshoot of the more generalized genus *Chamaepsila*. However, it will be shown below that even the latter genus should be considered as a residual taxon including species of ambiguous affinities.

Hendel (1934) described the genus *Synaphopsila* for one Chinese species, *S. hummeli* Hendel, 1934, which is characterized by the presence of three vertical setae instead of two setae present in *Oxypsila*. Later, Wang & Yang (1996) synonymized the two genera and included *S. hummeli* and three new Chinese species in *Oxypsila*. While studying *S. hummeli*, new differences compared with *P. abdominalis* were found, like the absence of notopleural setae (as it is also the case in *Psilosoma* Zetterstedt, but one notopleural seta is present in *P. abdominalis*). There are evidences that *S. hummeli* (and further 9 East Palaearctic species of the same group) does not form a monophylum with *P. abdominalis*. *Synaphopsila* is probably closer related to *Psila* s. str. and therefore considered here to be a subgenus of the latter.

Frey (1925) proposed the genus *Tetrapsila* for *Psila obscuritarsis* Loew, 1856, a species with four scutellar setae (two pairs), which was formerly placed in

*Chamaepsila* whose species have only one (pair of) apical scutellar setae. Later, Séguy (1936) added *Tetrapsila longipennis* Séguy, 1936, from the Açores Islands to the genus. This species, however, belongs in our opinion to *Afropsila* Shatalkin, and its inclusion in *Tetrapsila* was based on morphological similarity. It is characterized by black halteres in the female and some other features which are typical for *Afropsila*. The number of scutellar setae is not of generic value, as two pairs are also present in "*Chyliza*" *gracilis* Loew (see below) and the Asian *Xenopsila* Buck (Buck & Marshall, 2006a).

Zetterstedt (1860) described the genus *Psilosoma* for the two species *Scatophaga audouini* Zetterstedt, 1835, and *Scatophaga lefebvrei* Zetterstedt, 1835. The status of this genus, however, is not established. Some authors, like Hennig (1941), Soós (1984) or Pape (2007), considered it as a good genus different from *Psila* s. lat. But Collin (1944) expressed some doubts "whether these two species are generically distinct" from *Psila* and he treated *Psilosoma* as subgenus of *Psila*. This opinion was followed by Shatalkin (1986, 1989) and Iwasa (1998). *Psilosoma* differs from *Psila* and *Chamaepsila* by the absence of notopleural and supra-alar setae, the expanded and curved hind femur in the male, and the laterally compressed ovipositor in the female. The male terminalia are also peculiar with their long, dilated and poorly sclerotized aedeagus (Shatalkin, 1986, plate 1, figs 3-4). Notopleural setae are also absent in *Synaphopsila* Hendel. The two genera differ in addition to some external characters also in their distribution. *Psilosoma* is an European genus whereas species of *Synaphopsila* occur in the Russian Far East, China, Korea and Japan. Pending a cladistic analysis of this group of genera we are following the tradition of European dipterists and treat *Psilosoma* in the present paper as a good genus.

Hennig (1941) described *Psila problematica* from Germany. However, a comparison of its type with that of *Chamaepsila sibirica* Frey, 1925, showed that they are conspecific and they were synonymized by Shatalkin (1986). He proposed for this species a new subgenus in *Psila*, *Freyopsila* Shatalkin, 1986, in order to accommodate species of *Psila* without postocellar setae. This group contains currently eight species which are mainly distributed in the Eastern part of the Palaearctic Region.

Another problem concerns American species of *Psila* s. lat. with an elongated postpedicel for which Johnson (1920) described the genus *Pseudopsila* (type species: *Loxocera fallax* Loew, 1869). Later, Frey (1955) described two Oriental species from Myanmar (*Pseudopsila maculipennis* and *P. nigricollis*) and Shatalkin (1983) added the first Palaearctic species to the genus (*P. nigrifulva*). A careful study of the types of the two species described by Frey and the Nearctic *Pseudopsila collaris* (Loew, 1869) and *P. lateralis* (Loew, 1860) revealed that *P. nigrifulva* does not belong to this genus but seems to be closer related to *Psila sibirica* (Frey), and it was transferred to *Freyopsila* (Shatalkin, 1983). More recently, Buck & Marshall (2006a) revised the Nearctic species of *Pseudopsila* and concluded based on a cladistic analysis that the type species of *Pseudopsila* (*L. fallax*), as well as two other species, should be synonymized with *Psila* s. str. and proposed *Xenopsila* as new subgenus of *Psila* for the other Nearctic species previously placed in *Pseudopsila* (*P. bivittata*, *P. collaris*, *P. lateralis*) as well as for the Oriental and Palaearctic species (*P.* (*X.*) *arbustorum* Shatalkin, *P.* (*X.*) *nemoralis* Shatalkin, *P.* (*X.*) *tetrachaeta* Shatalkin).

Among European *Psila* s. lat. a short comment should be made for *Chyliza gracilis* Loew, 1854, which is characterized by a long, finely setulose, white arista. Freidberg & Shatalkin (2009) presented a review of its confusing taxonomic history. After a careful study of six specimens from Cyprus, Israel and Turkey they concluded that this species should be transferred in *Chamaepsila* thus becoming a junior homonym of *Psila gracilis* Meigen, 1826 which is now considered to be a synonym of *Chamaepsila buccata* (Fallén, 1826). Therefore, they proposed the replacement name *Chamaepsila setalba* Freidberg & Shatalkin, 2009 for *Chyliza gracilis* Loew, 1854. However, its combination of characters differs from other species of *Chamaepsila* and it represents probably a separate lineage within the genus. Moreover, a single female from Bulgaria (Sandanski) differs in some points from *Ch. setalba* and may represent another yet undescribed species. Therefore, further studies based on more specimens are needed in order to propose well-funded arguments for the generic position and for the intra-specific variability of the included taxa.

A long-lasting debate is dividing students of the family Psilidae. Whereas some authors consider the various taxa of *Psila* s. lat. as valid genera (Hennig, 1941; Soós, 1984; Pape, 2007), others treat them as subgenera of *Psila* s. lat. (Shatalkin, 1989, 2008; Iwasa, 1998). Based on a morphological analysis of external characters alone this question cannot be resolved. The differences ("gaps") between the taxa are weightened in a different manner by each student, and apparently "good" characters in one biogeographical region may be unreliable in other areas because of intermediate species or species-groups. For instance, the Non-European taxon *Xenopsila* described as subgenus of *Psila* (Buck & Marshall, 2006a) is characterized by a most peculiar type of male terminalia with a long, thin, scerotized aedeagus. But some species of *Loxocera*, in particular the *L.* (*Imantimyia*) *achaeta* group (including the Nearctic species *L. cylindrica* Say, *L. fumipennis* Coquillett, *L. ignyodactyla* Buck, the Japanese *L. lutulenta* Iwasa and the Palaearctic *L. achaeta* Shatalkin and *L. nigrifrons* Macquart) are similar and overlap with those of *Xenopsila*.

Species of *Freyopsila*, *Psilosoma*, *Synaphopsila* and (*Chamaepsila* + *Psila*) form a group which is characterized by a similar, more simple structure of male terminalia. Male terminalia of *Psila* s. str. and *Chamaepsila* resemble each other and are clearly separated from the other genera and represent a third level of the structure of the male terminalia. If only European species of the two taxa are considered then they form clearly two distinct groups which would deserve generic rank. However, with the inclusion of Asian species differences between them become unreliable because of species with an intermediate combination of characters. For this reason Iwasa (1998) treated *Chamaepsila* as a subgenus of *Psila* s. lat. It is therefore not surprising that the Japanese species *Psila magna* (Shatalkin, 1983) was described as *Chamaepsila* because it has a well developed postocellar seta as it is the case for other *Chamaepsila*. On the other hand, *Psila nigripalpis* Shatalkin, 1983, is similar to some species of *Chamaepsila*, in particular of the *Ch. rufa* group, but lacks the postocellar setae and was described originally in *Psila*.

Based on these problems all available species of the two taxa were studied again in detail in order to redefine their generic placements. It was found that a new character, the presence of fine, inconspicuous setulae on the posterior half of the

anepimeron, is a constant character for species of *Psila* s. str. Such setulae are absent in all species of *Chamaepsila* (except for one species, *Chamaepsila fenestralis* Shatalkin, 1983, from Russian Far East) and other taxa of *Psila* s. lat. For this reason we propose here to treat *Chamaepsila* and *Psilosoma* as distinct genera and exclude them from *Psila* s. str. Some characters which were found to be of diagnostic value for the various taxa of *Psila* s. lat. are summarized in Tab. 1.

TAB. 1. Diagnostic characters of *Psila* s. lat. In ( ): exceptions, see species listed below

| Characters / Taxa | Notopleural setae | Anepimeron with [s]etulae or [b]are | Postocellar setae | Dorsocentral setae | Vertical setae | Scutellar setae [pairs] | colour Arista y=yellow w=white | Postpedicel [l]ong as in *Loxocera* [m]edium,[s]hort |
|---|---|---|---|---|---|---|---|---|
| *Psila* s. str. spp. | 1 | (b), s | 0, 1 | (0), 1 | 2-3 | 1 | (w), y | (m), s |
| *P. abdominalis* | 1 | s | 0 | 0 | 2 | 1 | y | s |
| *P. crassula*, *P. magna* | 1 | s | 1 | 1 | 2 | 1 | y | s |
| *P. fallax* | 1 | b | 1 | 1 | 2 | 1 | w | m |
| *Chamaepsila* spp. | 1 | b, (s) | 1 | 1-4 | 2-3 | 1-2 | (w), y | (m), s |
| *Ch. fenestralis* | 1 | s | 1 | 1 | 2 | 1 | y | s |
| *Ch. obscuritarsis* | 1 | b | 1 | 1 | 3 | 2 | y | s |
| *Ch. setalba* | 1 | b | 1 | 1 | 2 | 1-2 | w | m |
| *Afropsila* spp. | 1 | b | 0 | 1 | 2 | 1-2 | w | s |
| *Asiopsila* spp. | 1 | b | 0-1 | 0-1 | 2 | 2 | w | l |
| *Freyopsila* spp. | 1 | b | 0, (1) | 1 | 2 | 1 | y | l, (m), s |
| *F. maculipennis* group | 1 | b | 1 | 1 | 2 | 1 | w | m |
| *Psilosoma* spp. | 0 | b | 0 | 0-1 | 2 | 1 | y | s |
| *Synaphopsila* spp. | 0 | b | 0 | 0-1 | 2-3 | 1 | w | s |
| *Xenopsila* spp. | 1 | b | 1 | 1 | 2 | 2 | w | m, s |

Genus ***Psila*** Meigen, 1803

TYPE SPECIES: *Musca fimetaria* Linnaeus, 1761, by subsequent designation of Westwood, 1840: 146.

DIAGNOSIS: Head large, yellow. Postocellar setae absent (present in some Chinese and Japanese species). Two vertical setae (three in some Chinese species). Mesonotum with one dorsocentral seta (absent in *P. abdominalis*). Scutellum with one (pair of) seta and with soft, scattered, marginal setulae. Anepimeron with soft, fine setulae in posterior half (also present in *Chamaepsila fenestralis* Shatalkin, 1983; this species and *Ch. bimaculata* Shatalkin, 1983, form an isolated group related to *Psila* s. str.).

DISTRIBUTION: *Psila* s. str. may be a comparatively young genus. It has a disjunct distribution in the Palaearctic Region with five West Palaearctic species, one species from the Kuril Islands and Japan (*P. magna* Shatalkin), and some species from the mountains of Western China.

KEY TO EUROPEAN SPECIES OF *PSILA* S. STR.

1a Anepimeron with soft, fine setulae in posterior half; postocellar setae absent (except for some Asian species); tarsus of mid leg ventrally with short, black setulae scattered among the golden setulae ........ *Psila* s. str. 2

1b Anepimeron bare; one postocellar seta present (except for most specimens of *Ch. setalba* Freidberg & Shatalkin and the East Palaearctic species *Ch. nigripalpis*); tarsus of mid leg ventrally with short yellow setulae . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Chamaepsila* spp.

2a Postpedicel about 2.5 times as long as its width at base, yellow but dark infuscated along dorsal margin; abdomen brownish to black; thorax yellow or reddish yellow with a darker stripe laterally the level of the supra-alar seta and the dorsal half of the anepisternum; dorsocentral setae absent. Body length: 6-1-7.3 mm. - Europe and Caucasus . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Psila* (*Oxypsila*) *abdominalis* Schummel, 1844

2b Postpedicel at most 1.5 times as long as its width at base, if yellow then without darkened dorsal margin; colouration of thorax different; one dorsocentral seta . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3

3a Postpedicel mostly black . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4

3b Postpedicel yellow, at most at base of arista with darkened spot . . . . . . . . . . . 5

4a Mesonotum and subscutellum yellow. Body length: 6.7-7.2 mm. - Caucasus . . . . . . . . . . . . . . . . . . . . . . . . . . *Psila* (s. str.) *caucasica* Mik, 1887

4b Mesonotum yellow, but with an unpaired black stripe medially extended almost to scutellum, and with a pair of black stripes from posterior end of postpronotal lobe to level of dorsocentral seta (sometimes these black stripes may be confluent). Subscutellum black. Body length: 6.5-7.0 mm. - Switzerland . . . . . . . . . . . . . . . . . . . . . ***Psila* (s. str.) *helvetica* sp. n.**

5a Eye kidney-shaped, distinctly higher than wide; postpedicel at base of arista with black spot; rays of arista about twice as long as its basal diameter. Body length: 7.7-8.8 mm. - Europe . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Psila* (s. str.) *fimetaria* (Linnaeus, 1761)

5b Eye roundish, only slightly higher than wide; postpedicel entirely yellow; rays of arista at most only little longer than its basal diameter. Body length: 8.3-8.5 mm - Europe . . . . . . *Psila* (s. str.) *merdaria* Collin, 1944

Subgenus ***Oxypsila*** Frey, 1925

TYPE SPECIES: *Psila abdominalis* Schummel, 1844, by monotypy.

***Psila* (*Oxypsila*) *abdominalis*** Schummel, 1844

MATERIAL SWITZERLAND: 1♂, VS, 640 m, Raron, 14 VII 1966, leg. L. & F. Keiser. – 1♀, VS, 623 m, Leuk-Platten, 3 VIII 1998, leg. Merz & Bächli.

COMMENTS: Wang & Yang (1996) described three species from China without postocellar and dorsocentral setae as *Oxypsila* (*O. altusfronsa*, *O. nigricorpa*, *O. unistripeda*), but without indication of the presence of the soft, fine setulae on the anepimeron which are characteristic for *P. abdominalis* and allow its placement in *Psila* s. str. (see diagnosis above). Because they were not available for examination their generic placement remains tentative.

*P. abdominalis* may be found in mountains of Central and Southern Europe. It is unknown from the British Isles (Collin, 1944; Chandler, 1998a), Holland (van der Goot & van Veen, 1996) and Scandinavia. Its northern border passes across Germany,

Czech and Slovak Republics, Hungary, and the Caucasus in the East. One specimen, however, was recently caught in the Moscow Region. It may therefore have a larger distribution than the few specimens of this rather rarely collected species in the museum collections indicate.

Subgenus ***Psila*** Meigen, 1803

***Psila* (s. str.) *fimetaria*** (Linnaeus, 1761)

MATERIAL SWITZERLAND: 2♀, BE, 1300 m, Zweisimmen, Gschwänd, 7 VI 2003, leg. B. Merz & M. Eggenberger. – 1♀, GE, 390-430 m, Dardagny, rivière de Roulave, 11 VIII 2000, leg. Merz & Bächli. – 1♂, GE, Avusy, Moulin de la Grave, 25 V 2006, leg. H. Boillat. – 1♀, GR, 1325 m, Ausserferrera, 30 VIII 2006, leg. B. Merz. – 1♀, GR, 1300-1670 m, Ausserferrera-Cresta, 1 IX 2006, leg. B. Merz. – 2♀, JU, 1000 m, La-Chaux-des-Breuleux, La Tourbière, 28 VI 2003, leg. B. Merz. – 1♀, SG, 910 m, Unterwasser, 11 VII 1997, B. Merz. – 2♀, VS, 1900-2200 m, Visperterminen, Giw-Gebidempass, 21 VII 2004, leg. B. Merz. – 1♀, VS, 1400 m, Visperterminen, Kreuz, 3 VI 2003, leg. B. Merz. – 1♀, VS, 1300 m, Morgins-En Tey, 22 VI 2003, leg. B. Merz. – 1♀, ZH, 400 m, Embrach-Haumüli, 24 VI 1995, leg. R. Wunderlin.

COMMENTS: This is one of the most common species of the family in Switzerland and may be found in various habitats from the lowlands to about 2200 m in the Alps.

***Psila* (s. str.) *helvetica*** sp. n. Figs P3-P4

HOLOTYPE: ♂, Switzerland, VS, 650 m, Leuk-Pfynwald, 23 IX 1992, leg. Merz & Otto (MHNG).

PARATYPES: 1♀, same data as holotype (MHNG). – 1♀, Switzerland, GR, 670-1100 m, Flims/Bergsturz, 13 IX 1993, leg. B. Merz (MHNG).

DIAGNOSIS: *P. helvetica* differs from other European species of *Psila* s. str. by the three black stripes on the mesonotum, the black subscutellum, the mostly black postpedicel, and the short, fine rays on the arista. This combination of characters is unique and *P. helvetica* occupies an isolated position in the genus (Figs P3, P4).

DESCRIPTION MALE

Measurements (n=1): Body length: 6.8 mm; wing length: 6.0 mm.

*Head*: Ground colour yellow. Ocellar triangle blackish. Antenna yellow, but postpedicel mostly black, 1.2 times as long as wide at base. Arista brown, conspicuously thickened at base, covered with short, thin rays. Eye roundish, small in profile compared to gena and parafacialia. Gena about 1.2 times higher than height of eye. Compound eye about 1.5 times higher than long. Width of frons about 1.1 times less than its length from the two posterior ocelli to the lunule. Width of frons about 1.8 times less than width of head. Frons uniformly yellow. Gena about 1.3-1.4 times less high than eye. Palpus yellow, black apically. Chaetotaxy (all setae black): 2 vertical setae; 1 fronto-orbital seta (?), postocellar seta absent.

*Thorax*: Ground colour yellow. Mesonotum with a broad, black stripe medially extending almost to scutellum. A pair of lateral black stripes from level of hind margin of the postpronotal lobe to level of dorsocentral seta. These lateral stripes may fuse partly with the unpaired medial stripe or be interrupted on level of suture. Subscutellum black. Anepimeron with fine, soft setulae in posterior half. Chaetotaxy (all setae black): 1 notopleural seta; 1 supra-alar seta; 1 postalar seta; 1 dorsocentral seta; 1 (pair of) apical scutellar seta, without soft, fine setulae along the margin.

*Legs*: Generally yellow. Middle tibia with two black apical spur-like setae of unequal size.

*Wing*: Entirely hyaline, with a slight yellowish tinge. Veins yellow. Section of M1+2 between R-M and DM-Cu about 1.5 times as long as previous section and subequal with apical section (between DM-Cu and margin). Haltere yellow.

*Abdomen*: Basal tergites black, other parts yellow. Terminalia not dissected.

FEMALE

*Measurements* (n=2): Body length: 6.5-7.0 mm; wing length: 7.0 mm.

*Comments*: Otherwise as male. Terminalia not studied.

***Psila* (s. str.) *merdaria*** Collin, 1944

MATERIAL SWITZERLAND: 1♀, GR, 1550 m, 3 km N Lenz, 11 VII 1996, leg. B. Merz. – 1♂, TG, 460 m, Ermatingen, Neuguet, 1 V 2002, leg. K. Grimm. – 1♀, ZH, 440 m, Zürich-Katzensee, 25 V 1996, leg. B. Merz.

COMMENTS: This species is morphologically similar to *P. fimetaria* and it is often difficult to separate them. It is a rather rare species which was described from Great Britain. Since then, it has been recorded from various Central European countries to the Moscow Region in the East and to Spain in the South (Pape, 2007; unpublished observations).

Genus ***Psilosoma*** Zetterstedt, 1860

TYPE SPECIES: *Scatophaga audouini* Zetterstedt, 1835, by original designation.

DIAGNOSIS: Two vertical setae. Postocellar seta absent. Notopleural seta absent. Dorsocentral seta present or absent. 1 (pair of) apical scutellar seta. Anepimeron bare. Hind femur in male (and also in the female of *P. audouini*) thickened. Male terminalia with long aedeagus. Female ovipositor compressed laterally and strongly sclerotized.

DISTRIBUTION: Two Western Palaearctic species are placed here which are distributed in cooler regions from Northern Scandinavia southwards to the Alps where they are usually found in higher altitudes. Both species are not uncommon in Switzerland in higher altitudes of the Alps where they may be often swept and observed on large stands of *Alnus viridis*.

***Psilosoma audouini*** (Zetterstedt, 1835)

MATERIAL SWITZERLAND: 1♂, 1♀, VS, 1600-2200 m, Visperterminen, Giw-Gebidem, 4 VII 2003, leg. B. Merz, J. Smit & M. van Det. – 1♀, VS, 1900-2200 m, Visperterminen, Giw-Gebidempass, 21 VII 2004, leg. B. Merz.

***Psilosoma lefebvrei*** (Zetterstedt, 1835)

MATERIAL SWITZERLAND: 1♂, GR, 2400 m, Lenzerheide, Piz Danis, 8 VIII 1992, leg. B. Merz. – 1♂, GR, 1500 m, Valbella-Casoja, 20 VII 1996, leg. B. Merz. – 1♂, GR, 2200 m, Ftan, Clünas, 5 VIII 1996, leg. Merz & Bächli. – 1♀, GR, 1300 m, Ausserferrera, 13 VIII 1991, leg. Merz & Freidberg. – 1♀, SZ, 1550 m, Pragelpass, 7 VIII 1995, leg. B. Merz.

Genus ***Chamaepsila*** Hendel, 1917

TYPE SPECIES: *Musca rosae* Fabricius, 1794, by original designation.

DIAGNOSIS: Arista yellow or slightly brownish, white only in *Ch. setalba* Freidberg & Shatalkin (other species with a white arista are excluded from this genus: *Psila fallax*, *Xenopsila* spp.); postocellar seta present (usually absent in *Ch. setalba*); 2-3 vertical setae; 1-6 dorsocentral setae; 1 notopleural seta; 1 (pair of) apical scutellar seta (except for *Ch. obscuritarsis* with 2 pairs); anepimeron entirely bare (except for *Ch. fenestralis* from the Russian Far East).

COMMENTS: Steyskal (1987) did not recognize this genus in his key to genera and subgenera of Nearctic Psilidae. One reason may be that *Psila* s. str. was not yet known from that region and he considered the subgeneric division of Hennig (1941) as less convincing. However, taking into account the observations during the present study and the results of the work of Buck & Marshall (2006a) this division is based on unequivocal characters which allow its safe identification (see key above).

***Chamaepsila atra*** (Meigen, 1826)

MATERIAL SWITZERLAND: 2♂, BE, 1430 m, Lenk, Simmenfälle, 31 V 2003, leg. B. Merz & M. Eggenberger. – 1♀, BE, 995 m, Tramelan, La Tourbière, 4 VI 2003, leg. B. Merz, J.-P. Haenni & M. Rapp. – 1♂, GR, 2200-2550 m, Juf-Stallerberg, 19 VI 1994, leg. B. Merz. – 1♂, GR, 2250-2490 m, Lenzerheide, Piz Danis, 12 VII 1996, leg. B. Merz. – 1♂, GR, 1500 m, Valbella, Casoja, 19 VII 1997, leg. B. Merz. – 1♀, TI, 1965 m, Piora, 11 VI 1996, leg. M. Bernasconi. – 1♂, 2♀, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 1♂, 1♀, VS, 1700-1950 m, Morgins, Portes du Soleil (Monthey), 22 VI 2003, leg. B. Merz. – 1♂, VS, 1400 m, Visperterminen, Kreuz, 3 VI 2003, leg. B. Merz.

COMMENTS: This Transpalaearctic species is characterized by the presence of 4 dorsocentral setae, this character only shared with *Ch. clunalis* (Collin, 1944) in the Western Palaearctic Region. *Ch. clunalis* was described from Great Britain and was later found in Central Europe and Spain but is still unknown from Switzerland (Pape, 2007). It differs from *Ch. atra* by its larger epandrium in the male which gives the impression that the abdomen is parallel-sided (in *Ch. atra* more cone-like). Moreover, the posteroventral margin of the epandrium is extended into a tooth-like projection (Shatalkin, 1986, plate 4, fig. 9) (evenly rounded in *Ch. atra*). Finally, the female of *C. clunalis* has therefore a wider 7th tergite which is as wide as the previous one (decreasing in width in *C. atra*). *C. clunalis* exhibits a wide variation in colouration, varying from black to brown, especially on the head.

***Chamaepsila bicolor*** (Meigen, 1826)

MATERIAL SWITZERLAND: 1♂, GR, 2100 m, Ftan-Clünas, 5 VIII 1996, leg. B. Merz & G. Bächli. – 1♂, GR, 1660 m, S Chanf-Flin, 7 VIII 1996, leg. B. Merz & G. Bächli. – 1♀, VS, 1550 m, Jeitzinen, 26 VI 1999, leg. B. Merz & M. Eggenberger. – 2♂, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 2♂, VS, 2040 m, Morgins, Pointe de Bellevue, 21 VI 2003, leg. B. Merz. – 1♀, VS, 1390 m, Visperterminen/Kreuz, 3 VII 2003, leg. B. Merz, J. Smit & M. van Det.

COMMENTS: The specimens from "Pointe de Bellevue" are characterized by the brown stripe on the pleura and fit therefore the description of *Ch. nigromaculata* (Strobl, 1909). The two species were later synonymized (Carles-Tolrá, 1993a). The males from Switzerland correspond well with the illustration of the lectotype of *Ch. bicolor* with the medially directed teeth on the epandrium (Soós, 1985, fig. 1A). On the other hand, the structure of the paramere without the tooth on the protuberance (see

Carles-Tolrá, 1993a, fig. 6) is more similar to *C. quadrilineata* (Strobl, 1898). Further studies are necessary in order to establish the identity of these Swiss specimens.

***Chamaepsila buccata*** (Fallén, 1826)

*Psila gracilis* Meigen, 1826; synonymy by Soós (1985).

MATERIAL SWITZERLAND: 1♀, GR, 680 m, Rothenbrunnen, 8 VIII 1996, leg. B. Merz & G. Bächli. – 1♂, 1♀, VS, 750 m, Branson/Follatères, 29 III 2002, leg. B. Merz.

COMMENTS: *Chamaepsila buccata*, *Ch. sardoa* (Rondani, 1876) and *Ch. rozkosnyi* Carles-Tolrá, 1993, form a morphologically uniform group. *Ch. sardoa* has an entirely black antenna (basal segments yellowish in *Ch. buccata*), 2 dorsocentral setae (1 dorsocentral seta in *Ch. buccata*), is on average smaller (3-4 mm, *Ch. buccata* 4-6 mm) and differs in the structure of the male terminalia (Shatalkin, 1986, plate 2, fig. 5 for *Ch. buccata* (as *Ch. gracilis* Meigen) and plate 3, fig. 1 for *Ch. sardoa*). *Ch. rozkosnyi* is characterized by the presence of 2 fronto-orbital setae (1 fronto-orbital seta in *Ch. buccata* and *Ch. sardoa*) and in details of the structure of the male terminalia with a longer aedeagus (Carles-Tolrá, 1993b).

*Chamaepsila buccata* has a transpalaearctic distribution. Outside Europe it is reported from Mongolia (Soós, 1974), China (Wang & Yang, 1996), and the Russian Far East (Shatalkin, 1986).

***Chamaepsila confusa*** sp. n. Fig. 1

HOLOTYPE: ♂, CH (=Switzerland), VS, 600 m, Leuk-Pfynwald, 25 VIII 2001, leg. Merz & Landry (MHNG).

PARATYPES: 1♂, same data as holotype (MHNG). – 1♀, Switzerland, TI, 460 m, Clivio, Arzo, 4 X 2003, LF [= Lichtfalle, = light trap], leg. H. Vicentini (MHNG). – 1♀, France, Haute-Savoie (74), Pormenaz, 1700-2200 m, 8-31 VII 2003, MTA [Malaise-trap], leg. Castella & Speight (MHNG).

DIAGNOSIS: Externally, this species is similar to *Ch. persimilis* (Wakerley) and *Ch. nigricornis* (Meigen). It shares with *Ch. persimilis* the presence of a yellow spot dorsally the anterior spiracle, but differs in the apically black palpus and the entirely black postpedicel. *Ch. nigricornis* has an entirely black pleuron including the propleuron. The three species differ further in details of the male terminalia, in particular in the shape of the aedeagus and the epandrium.

DESCRIPTION MALE

*Measurements* (n=2): Body length: 3.7 mm; wing length: 3.9 mm.

*Head*: General colour yellow but with black ocellar triangle and a pair of narrow, black stripes on the occiput from vertex (between medial vertical setae) to the occipital foramen. Scape and pedicel yellow, postpedicel black, about 1.3 times as long as basal width. Arista brownish, short setulose, longest rays shorter than diameter of arista at base. Frons about as long as wide. Gena (in paratype) about 1.2 times less high than height of compound eye. Compound eye about 1.4 times as high as wide. Palpus black apically. Chaetotaxy (all setae yellow): 3 vertical setae; 1 stout postocellar seta; 2 fronto-orbital setae.

*Thorax*: Almost entirely black, but with a yellow spot on propleuron dorsally of anterior spiracle. Chaetotaxy (all setae yellow): 1 notopleural seta; 1 supra-alar seta; 1

postalar seta; 2 dorsocentral setae posterior suture; 1 (pair of) apical scutellar seta. Anepimeron bare.

*Legs*: Entirely yellow.

*Wing*: Hyaline with yellowish veins. Section of M1+2 between crossveins R-M and DM-Cu about three times as long as section between BM-Cu and R-M and subequal to section between DM-Cu and wing margin. Haltere yellowish white.

*Abdomen*: Entirely black. Male terminalia as in fig. 1.

FEMALE

*Measurements* (n=2): Body length: 4.2 mm; wing length: 4.3 mm.

*Comments*: Otherwise as male.

COMMENTS: The male terminalia are characteristic for *Ch. confusa*. The base of the aedeagus is convex (fig. 1), but concave in *Ch. nigricornis* (Lyneborg, 1964; Shtakel'berg, 1989; van der Goot & van Veen, 1996). *Ch. persimilis* is characterized by a special type of the aedeagus which has a strong desclerotization at its base in the middle (figs 4-5).

***Chamaepsila humeralis*** (Zetterstedt, 1847)

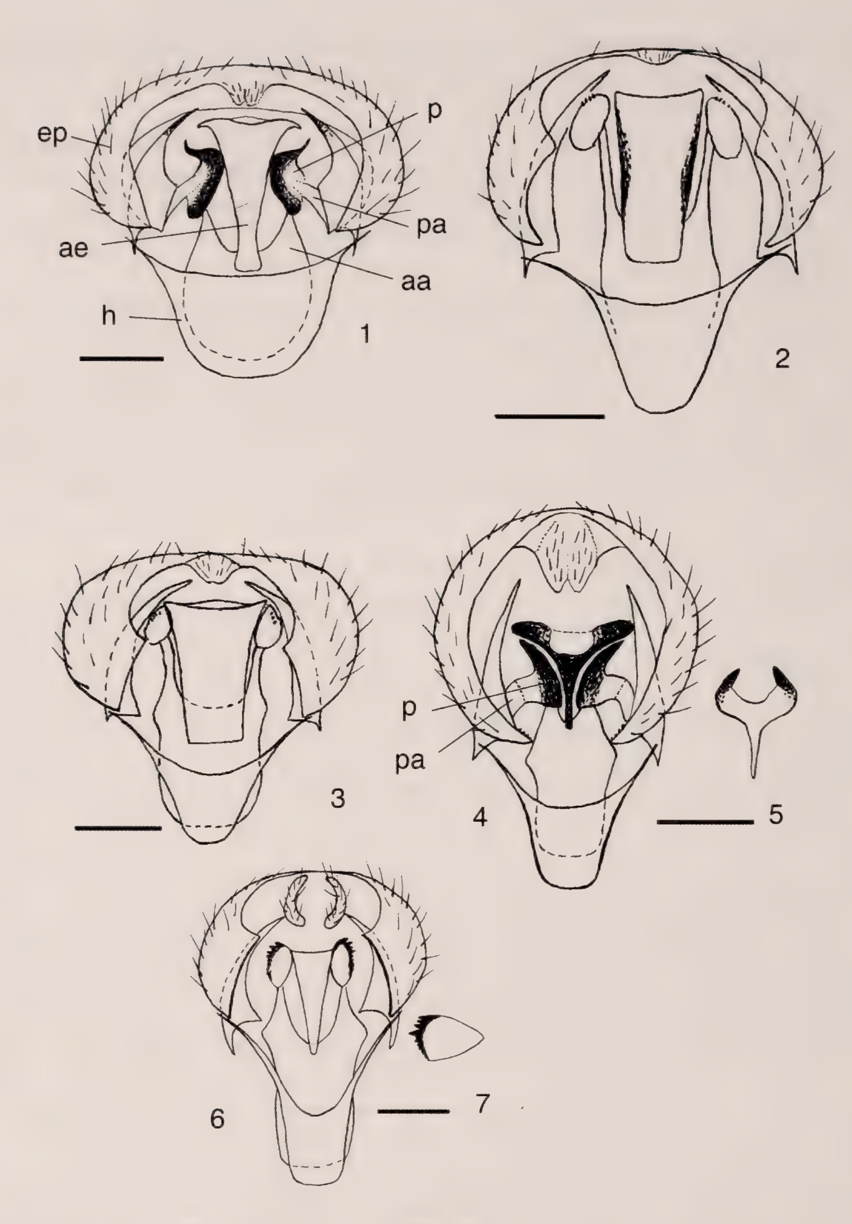
MATERIAL SWITZERLAND: 1♀, BE, 650-950 m, Mt. Raimeux, Corcelles, 2 VI 2003, leg. B. Merz. – 1♂, GL, 1130 m, Richisau (Klöntal), 10 IX 1997, leg. B. Merz. – 1♂, 1♀, GL, 850 m, Vorauen (Klöntal), 10 IX 1997, leg. B. Merz. – 6♂, 7♀, GR, 1300-1670 m, Ausserferrera-Cresta, 28 VIII-1 IX 2006, leg. B. Merz. – 1♀, GR, 980 m, Andeer (Hinterrhein), 29 VIII 2006, leg. B. Merz. – 2♂, GR, 1500 m, Valbella, Casoja, 21 VII 1997, leg. B. Merz. – 1♀. TI, 460 m, Clivio, Arzo, 4 X 2003, LF (= light trap), leg. H. Vicentini. – 1♂, VD, 1300 m, St.Cergue, Barillette, 3 VIII 2003, B. Merz. – 2♂, 1♀, VS, 1300 m, Morgins, En Tey, 22 VI 2003, leg. B. Merz. – 1♀, VS, 1600-2200 m, Visperterminen, Giw-Gebidem, 4 VII 2003, leg. B. Merz, J. Smit & M. van Det.

COMMENTS: This species is well characterized by the presence of an entirely yellow postpronotal lobe and propleuron and thus differs from other species with mainly black thorax and the same chaetotaxy (*Ch. confusa*, *Ch. nigricornis*, *Ch. persimilis*, *Ch. rosae*). The Swiss specimens show a remarkable variability in the colour of the anepimeron. Whereas the anepimeron is usually black in this species, it is yellow in the specimens from Morgins. The male terminalia, however, are the same in both colour morphs and they are considered here to belong to the same species.

One male deserves a comment. It carries the following labels: "Helv., VD, 1300 m, St. Cergue, Barillette, 3 VIII 2003, leg. B. Merz". It differs from typical specimens of *Ch. humeralis* by a black mesonotum with a yellow longitudinal stripe between the postpronotal lobe and the wing base, and on the dorsal half of the pleuron. The anepisternum is black in the posterior half and the anepimeron slightly brownish. The study of the male terminalia, however, does not show any difference and it is concluded that this specimen is an extreme colour form of *Ch. humeralis*. A more detailed interpretation of the status of this colour morph can only be obtained by the study of additional specimens.

***Chamaepsila limbatella*** (Zetterstedt, 1847)

MATERIAL SWITZERLAND: 1♀, GR, 2100 m, Ftan-Clünas, 5 VIII 1996, leg. B. Merz & G. Bächli. – 1♀, GR, 1500 m, Valbella, Casoja, 19 VII 1997, leg. B. Merz. – 1♀, VS, 1900-2100 m, Visperterminen, Rothorn-Giw, 30 VII 1998, leg. B. Merz & G. Bächli.




FIGS 1-7

Male terminalia of *Chamaepsila* spp. (1) *Ch. confusa* sp. n., ventral view (holotype, CH, VS, 600 m, Leuk-Pfynwald, 25 VIII 2001). (2) *Ch. pallida* (Fallén), ventral view (CH, BE, Mt. Raimeux, Corcelles, 2 VI 2003). (3) *Ch. pallida* (Fallén), ventral view (Russia, Moscow Region, Golitsyno, 23 VI 1981). (4) *Ch. persimilis* (Wakerley), ventral view (CH, VS, Eggerberg-Erb, 24 VI 2000). (5) *Ch. persimilis* (Wakerley), aedeagus (F, Haute Savoie, Monnetier, Petit Salève, 24 VIII 2003). (6) *Ch. unilineata* (Zetterstedt), ventral view (CH, TI, 1097 m, Mte. S. Giorgio, top, 18 V 2006). (7) *Ch. unilineata* (Zetterstedt), paramere, lateral view (same data).
Abbreviations: *aa* = aedeagal apodeme; *ae* = aedeagus; *ep* = epandrium; *h* = hypandrium; *p* = paramere; *pa* = parameral arm.

COMMENTS: This is a rare European species which is easy to identify with its black body and its chaetotaxy with 3 vertical setae, 1 fronto-orbital seta, and 1 dorsocentral seta (all pale).

***Chamaepsila morio*** (Zettestedt, 1835)

MATERIAL SWITZERLAND: 4♂, 1♀, BE, 1430 m, Lenk, Simmenfälle, 31 V 2003, leg. B. Merz & M. Eggenberger. – 1♂, GR, 2250-2490 m, Lenzerheide, Piz Danis, 12 VII 1996, leg. B. Merz. – 4♀, GR, 1520 m, Lenzerheide/Sundroina, 17 V 1997, leg. B. Merz. – 1♀, GR, 1490 m, Valbella, Casoja, 11 VII 1998, leg. B. Merz. – 2♀, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 1♂, 1♀, VS, 1700-1950 m, Morgins, Portes du Soleil (Monthey), 22 VI 2003, leg. B. Merz. – 1♀, VS, 1900-2200 m, Visperterminen, Giw-Gebidempass, 21 VII 2004, leg. B. Merz. – 3♀, VS, 1600-2200 m, Visperterminen, Giw-Gebidem, 4 VII 2003, leg. B. Merz, J. Smit & M. van Det. – 1♀, VS, 1400 m, Visperterminen/Kreuz, 3 VI 2003, leg. B. Merz. – 1♀, VS, 1300-1900 m, Visperterminen, Richtung Giw, 15 VII 1995, leg. B. Merz.

COMMENTS: *Chamaepsila morio* is widespread in Scandinavia and Nothern Russia. In the South it is mainly known from higher altitudes of the Alps. In the Eastern parts of the Palaearctic Region it is recorded from the Altai Mountains, Yakutia and Magadan (but only females are known from the latter two localities). Soós (1974) identified this species from Mongolia based on three females.

***Chamaepsila nigra*** (Fallén, 1820)

MATERIAL SWITZERLAND: 1♀, GE, 350 m, Cartigny, Moulin de Vert, 22 IV 2000, leg. B. Merz. – 1♀, GR, 1550 m, Lenzerheide/Sundroina, 20 VII 1997, leg. B. Merz. – 1♀, GR, 1500 m, Valbella, Casoja, 19 VII 1997, leg. B. Merz. – 1♀, VS, 1600-2200 m, Visperterminen, Giw-Gebidem, 4 VII 2003, leg. B. Merz, J. Smit & M. van Det. – 1♂, 1♀, VS, 1400 m, Visperterminen/Kreuz, 3 VI 2003, leg. B. Merz.

***Chamaepsila nigricornis*** (Meigen, 1826)

MATERIAL SWITZERLAND: 1♀, BE, 650-950 m, Mt. Raimeux, Corcelles, 2 VI 2003, leg. B. Merz. – 2♂, GE, 420 m, Bernex, Bois de Carabot, 29 IV 2005, leg. B. Merz. – 2♀, GE, 510 m, Bernex-Signal, 24 IV 2003, leg. B. Merz & F. Amiet. – 1♂, GE, 500 m, Bernex-Signal, 30 IV 2007, leg. B. Merz. – 1♀, GE, Avusy, Moulin de la Grave, 15 V 2003, leg. H. Boillat. – 1♂, GR, 1600 m, Lenzerheide/Sundroina, 16 VII 2000, leg. B. Merz. – 1♂, 2♀, GR, 1300-1325 m, Ausserferrera, 28-30 VIII 2006, leg. B. Merz. – 1♀, JU, 1000 m, Le Chaux, Les Breuleux, La Tourbière, 28 VI 2003, leg. B. Merz. – 1♀, TI, 370m, Cugnasco-Montedato, 2 IV 2007, B. Merz. – 1♀, TI, 205 m, Gordola, Verzascaufer, 1 IV 2007, leg. B. Merz. – 1♀, VS, 650 m, Baltschieder, Chumme, 23 V 1998, leg. B. Merz. – 1♂, VS, 920 m, Leuk-Brentjong, 15 V 2000, leg. B. Merz. – 1♂, VS, 625 m, Leuk-Platten, 2 V 1999, leg. B. Merz. – 1♀, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 2♂, VS, 1550 m, Visperterminen, ob Dorf, 27 VIII 2001, leg. B. Merz & B. Landry. – 2♀, ZH, 430 m, Zürich-Allmend, 6 V 1998, leg. B. Merz. – 1♀, ZH, 630 m, Zürich-Zürichberg, 6 IX 1992, leg. B. Merz.

COMMENTS: *Chamaepsila nigricornis* is known as a pest of *Chrysanthemum* sp. with its larvae feeding in the roots (Vernon, 1962; Iwasa, 1998). Morphologically, it can be confused with *Ch. confusa*, *Ch. persimilis*, and *Ch. rosae* which have the same general body colouration and chaetotaxy. However, their male terminalia are different and allow an easy identification (Wakerley, 1959; Lyneborg, 1964; Wang, 1988; Shtakel'berg, 1989).

***Chamaepsila obscuritarsis*** (Loew, 1856)

MATERIAL SWITZERLAND: 1♂, ZH, 650 m, Zürich-Zürichberg, 16-20 VI 1995, MF [=Malaisefalle], leg. S. Ungricht.

COMMENTS: With its two (pairs of) scutellar setae this species is unique within *Chamaepsila*. For this reason Frey (1925) proposed the genus *Tetrapsila* for it with the remark that this genus may be only a subgenus of *Chamaepsila*. The two genera were indeed synonymized later (Shatalkin, 1986; Iwasa, 1998).

***Chamaepsila pallida*** (Fallén, 1820) Figs 2-3, P5-P6

MATERIAL SWITZERLAND: 1♂, 1♀, BE, 650-950 m, Mt. Raimeux, Corcelles, 2 VI 2003, leg. B. Merz. – 1♀, BE, Burgdorf, leg. Meyer-Dür (small specimen). – 2♀, GR, 1530-1540 m, Valbella, Casoja, 14-15 VII 1998, leg. B. Merz. – 1♂, GR, 1530 m, Valbella, Casoja, 19 VII 1997, leg. B. Merz. – 1♀, GR, 1430 m, Zernez, Gondas, 6 VIII 1996, leg. B. Merz & G. Bächli. – 3♀, VS, 1400 m, Visperterminen, 14 VII 1995, leg. B. Merz.

DIAGNOSIS: *Ch. pallida* is morphologically similar with *Ch. luteola* (Collin, 1944). They have both a yellow body. The latter differs from *Ch. pallida* by other proportions of its eye, the brownish dorsal border of the postpedicel (uniformly yellow in *Ch. pallida*), the brownish yellow setae on head and thorax (yellow in *Ch. pallida*) and the structure of the male terminalia (Wang, 1988). Two other species, *Ch. nigrosetosa* Frey, 1925, and *Ch. unilineata* (Zetterstedt, 1847), were often synonymized with *Ch. pallida*. According to our studies we treat them here as good species. They may be separated from each other with the key provided at the end of this chapter.

COMMENTS: K. Holston from the NRS kindly made available photos of the entire type series of *Scatophaga pallida* Fallén (figs P5-P6). It contains one male, six females, and one specimen without abdomen. The male (fig. P5) and one female (fig. P6) carry an identification label in Fallén's handwriting. The male is labelled "S. pallida" (underlined), ♂ (written on the second line). The type locality is according to the original description "Esperöd" in Southern Sweden (Fallén, 1820). The specimen without abdomen belongs to another species, probably *Chamaepsila rufa* (Meigen, 1826), with its black setae on head and thorax. The abdomen is darkened in two females, and one of them has also the tip of the palpus darkened. They correspond probably to the description of Var. β of Fallén. The male and the other four females are yellow including the palpus and are considered here as syntypes of *Ch. pallida* Fallén s. str. A short description of the male syntype (fig. P5) based partly on the study of the photos is provided here.

DESCRIPTION MALE

*Head*: Mostly yellow, but ocellar triangle blackish. Antenna entirely yellow, postpedicel about 1.6 times as long as wide at base. Arista yellowish, short setulose. Gena about 1.2 times less high than eye. Palpus yellow. Chaetotaxy (all setae light yellowish): 3 vertical setae; 1 stout postocellar seta; 2 fronto-orbital setae.

*Thorax*: Yellow including subscutellum. Chaetotaxy (all setae light yellowish): 1 notopleural seta; 2 dorsocentral setae posterior of suture; 1 (pair of) apical scutellar seta.

*Legs*: Yellow.

*Wing*: Hyaline with yellowish veins. Section of M1+2 between R-M and DM-Cu about 2.9 times as long as previous section (between BM-Cu and R-M) and slightly longer than last section (between DM-Cu and wing margin). Haltere yellowish white.

*Abdomen*: Entirely yellow. Genitalia (figs 2-3) with a wide aedeagus; paramere without a distinct, large tooth.

***Chamaepsila pectoralis*** (Meigen, 1826)

MATERIAL SWITZERLAND: 1♀, GR, 980 m, Andeer-Clugin, 17 VI 1994, leg. B. Merz. – 1♀, GR, 1490 m, Valbella-Casoja, 26 VII 1999, ZF, leg. B. Merz. – 1♂, SG, 610 m, Wattwil, 11 VII 1997, leg. B. Merz. – 1♀, ZH, 400 m, Embrach-Haumüli, 4 VI 1998, leg. C. Wolf.

COMMENTS: The specimen from Valbella was collected in a tent-trap.

***Chamaepsila persimilis*** (Wakerley, 1959) Figs 4-5

MATERIAL SWITZERLAND: 1♂, GE, Corsier-Port, vitre véranda, 3-15 VIII 2003, leg. C. Besuchet. – 1♂, 1♀, GE, 420 m, Dardagny/Roulave, 30 VI 2001, leg. B. Merz. – 1♂, GE, 360 m, Dardagny, Le Moulin, 30 VI 2001, leg. B. Merz. – 1♀, GE, 350 m, Cartigny, Moulin de Vert, 5 VI 2006, leg. B. Merz. – 1♂, GE, 360 m, Dardagny, Le Moulin, 8 VII 2002, leg. B. Merz. – 1♀, GR, 980 m, Andeer (Hinterrhein), 29 VIII 2006, leg. B. Merz. – 5♀, GR, 350 m, Grono (Dorf), 31 VIII 2006, leg. B. Merz. – 2♀, GR, 330 m, Grono (Moesa), 31 VIII 2006, leg. B. Merz. – 1♀, SG, 610 m, Wattwil, 11 VII 1997, leg. B. Merz. – 2♂, 1♀, VS, 460-750 m, Branson/Follatères, 9 VI 2004, leg. B. Merz & J.-P. Haenni. – 1♀, VS, 1550 m, Visperterminen, ob Dorf, 27 VIII 2001, leg. B. Merz & B. Landry. – 2♂, VS, 920 m, Leuk-Brentjong, 15 V 2000, leg. B. Merz. – 1♂, 2♀, VS, 745 m, Visp, Hohbrunne, 3 VI 2003, leg. B. Merz. – 1♂, ZH, 530 m, Zürich-Hönggerberg, 16 VI 1998, leg. B. Merz.

COMMENTS: The aedeagus of this species is unique. According to the available illustrations (Wakerley, 1959; Lyneborg. 1964; van der Goot & van Veen, 1996) and our observations (figs 4-5) it has a deep incision at its base which may be interpreted as a desclerotized area. In contrast, the lateral basal protuberances are strongly sclerotized. Moreover, the epandrium is unique by its extended and apically narrowed posteroventral margin (fig. 4).

***Chamaepsila quadrilineata*** (Strobl, 1898)

MATERIAL SWITZERLAND: 1♀, VS, Jeitzinen, Ägerde, 3 VII 2001, leg. B. Merz. – 3♂, 2♀, VS, 1700-1900 m, Morgins, La Chaux-Culet, 21 VI 2003, leg. B. Merz. – 3♀, VS, 2040 m, Morgins, Pointe de Bellevue, 21 VI 2003, leg. B. Merz.

***Chamaepsila rosae*** (Fabricius, 1794)

MATERIAL SWITZERLAND: 1♂, GR, 1520 m, Lenzerheide-Sundroina, 12 VII 1999, leg. B. Merz. – 1♂, GR, 1490 m, Valbella-Casoja, 24 VII 1999, leg. B. Merz. – 1♂, VS, 700-770 m, Raron, Heidnischbiel, 26 V 1999, leg. B. Merz. – 1♂, VS, 1600-2200 m, Visperterminen, Giw-Gebidem, 4 VII 2003, leg. B. Merz.

COMMENTS: This is the noxious "carrot fly" whose larvae are tunneling roots of carrot, celery, parsnip, parsley and other umbelliferous plant species (Grichanov *et al.*, 2005), It is widely distributed in the Palaearctic Region. In the Eastern Palaearctic Region it is recorded from China (Wang & Yang, 1996), Mongolia (Soós, 1974), the Amur area (Shatalkin, 1986), and the Sakhalin and Kuril Islands. Surprisingly it has not yet been found in the Primorye Territory of Russia, maybe because this species is replaced there by the morphologically (and maybe biologically) similar species *Ch. sonora* (Shatalkin, 1986) and *Ch. iwasai* (Shatalkin, 1996) which were found in a garden of a kitchen. Although *Ch. rosae* is known from Japan it is rare because another species, *Synaphopsila nartshukae* Shatalkin, 1986, is known to damage carrots (Iwasa *et al.*, 1987; Narita *et al.*, 2005). Later, the species was accidently introduced to North America where it is now a pest species (Hooper *et al.*, 2002) and to New Zealand (Evenhuis, 1989).

The name *Musca rosae* Fabricius, 1794, is a primary homonym of *Musca rosae* De Geer, 1776 (a junior synonym of the Syrphidae *Musca pyrastri* Linnaeus, 1758) (Thompson & Pont, 1994) and the new name *Chamaepsila hennigi* Thompson & Pont, 1994, was proposed for the carrot fly. Later, Chandler (1998b) requested the ICZN to preserve the name "rosae" for the carrot fly, and this proposition was accepted (ICZN, 1999).

The identity of the Swiss specimens was confirmed by dissection of the male terminalia and the comparison with illustrations published by Wakerley (1959), Lyneborg (1964) and Wang (1988).

***Chamaepsila sardoa*** (Rondani, 1876) - new for Switzerland

MATERIAL SWITZERLAND: 1♀, TI, 205 m, Gordola, Verzascaufer, 15 V 2006, leg. B. Merz. – 1♂, 1♀, TI, 205 m, Gordola, Verzascaufer, 1 IV 2007, leg. B. Merz.

COMMENTS: This species is in most respects similar to *Ch. buccata*. It may be separated from the latter and from *Ch. rozkosnyi*, another morphologically similar species, by the characters mentioned under *Ch. buccata*. *Ch. sardoa* is a Mediterranean species which has been found from Spain to Israel. The present finding in Southern Switzerland represents the northernmost record of this species. Outside the Western Palaearctic Region it was recorded from desert zones in Middle Asia and from Mongolia (Soós, 1974). The record from Myanmar by Frey (1955) is based on a misidentification. He compared his female from Mt. Kambaiti with a female from Morocco which he thought was *Ch. sardoa*. A careful study of both specimens revealed that they belong to two different species. The female from Morocco was later described as *Psila atlasica* Shatalkin, 2000, and the female from Myanmar as *Psila freyi* Shatalkin, 2000.

***Chamaepsila unilineata*** (Zetterstedt, 1847) stat. rev. - new for Switzerland Figs 6-7

MATERIAL SWITZERLAND:

A) TYPICAL SPECIMENS: 1♂, GR, 1000-1150 m, Brienz-Surava, 25 VII 1999, leg. B. Merz. – 1♀, GR, 1550 m, Lenzerheide/Sundroina, 20 VII 1997, leg. B. Merz. – 6♂, 3♀, GR, 1520 m, Lenzerheide/Sundroina, 10 VII 1998, leg. B. Merz. – 6♂, 2♀, GR, 1490 m, Lenzerheide/See, 11 VII 1998, leg. B. Merz. – 1♀, GR, 1500 m, Valbella, Casoja, 21 VII 1997, leg. B. Merz. – 1♀, GR, 1530 m, Valbella, Casoja, 14 VII 1998, leg. B. Merz. – 2♂, 3♀, GR, 1490 m, Valbella, Casoja, 24 VII 1999, leg. B. Merz. – 4♀, TI, 1097 m, Mte. S. Giorgio, top, 18 V 2006, leg. B. Merz. – 6♂, 3♀, VS, 1550 m, Jeitzinen, 26 VI 1999, leg. B. Merz & M. Eggenberger. – 4♂, 3♀, VS, 1500 m, Jeitzinen, Ägerde, 3 VII 2001, leg. B. Merz. – 1♂, VS, 1400 m, Visperterminen, 14 VII 1995, leg. B. Merz.

B) LONGITUDINAL STRIPES ON MESONOTUM BADLY EXPRESSED OR ABSENT: 1♂, GR, 980 m, Andeer, Clugin, 17 VI 1994, B. Merz. – 2♀, GR, 1550 m, 3 km N Lenz, 11 VII 1996, leg. B. Merz. – 2♂, 2♀, GR, 1520 m, Lenzerheide/Sundroina, 10 VII 1998, leg. B. Merz. – 1♀, GR, 1600 m, Lenzerheide/Sundroina, 16 VII 2000, leg. B. Merz. – 5♂, 1♀, GR, 1490 m, Lenzerheide/See, 11 VII 1998, leg. B. Merz. – 1♂, GR, 1500 m, Valbella, Casoja, 19 VII 1997, leg. B. Merz. – 3♂, 2♀, GR, 1490 m, Valbella, Casoja, 24 VII 1999, leg. B. Merz. – 2♂, 1♀, GR, 1000-1150 m, Brienz-Surava, 25 VII 1999, leg. B. Merz. – 2♂, TI, 1097 m, Mte. S. Giorgio, top, 18 V 2006, B. Merz. – 1♀, ZH, 350 m, Flaach, Thurauen, 6 VI 1993, leg. B. Merz.

C) KATEPISTERNUM BROWNISH: 1♀, GR, 1520 m, Lenzerheide/Sundroina, 10 VII 1998, leg. B. Merz. – 1♂, GR, 1490 m, Valbella, Casoja, 24 VII 1999, leg. B. Merz. – 5♂, 4♀, VS, 1550 m, Jeitzinen, 26 VI 1999, leg. B. Merz & M. Eggenberger. – 2♂, 1♀, VS, 1500 m, Jeitzinen, Ägerde, 3 VII 2001, leg. B. Merz.

COMMENTS: So far, this species has usually been synonymized with *Chamaepsila pallida* (Fallén). It was argued that the presence of three dark longitudinal stripes on the yellow mesonotum and the dark subscutellum fall within the colour variation of *Ch. pallida* (Hennig, 1941; Soós, 1984, 1985). However, a careful study including the structure of the male terminalia has shown that two species are involved. They differ in the colour of the subscutellum which is yellow in *Ch. pallida* but has a brown median stripe in *Ch. unilineata* A brief diagnosis of *Ch. unilineata* is provided here.

DESCRIPTION MALE

*Head*: Antenna with postpedicel yellow, rarely with a narrow or wide brownish dorsal margin. Arista rather long setulose (as in Hennig, 1941, fig. 19, right illustration); Palpus yellow.

*Thorax*: Mesonotum yellow, with a medial and a pair of lateral brown to black, narrow to wide stripes which may be conspicuous or more or less reduced or even almost absent. Subscutellum at least medially brown to black. Katepisternum yellow or with brown spot of various size.

*Male terminalia*: Aedeagus rather narrow, triangular. Paramere with four large teeth (figs 6-7).

***Chamaepsila villosula*** (Meigen, 1826)

MATERIAL SWITZERLAND: 4♂, GR, 2100 m, Ftan/Clünas, 5 VIII 1996, leg. B. Merz & G. Bächli. – 1♂, VS, 1500 m, Jeitzinen, Ägerde, 3 VII 2001, leg. B. Merz.

COMMENTS: This species is easy to identify because of its colouration, chaetotaxy and the male terminalia with the large epandrium. It is rarely collected and its distribution is therefore little known. Pape (2007) recorded it from Belgium, Germany, Czech and Slovak Republics, Hungary, and Switzerland. Recently, it was found in Italy (Verona province, Chiesa S. Michele, 26 VI 2001, leg. B. Merz & F. Mason, MHNG) and in France (Hautes-Alpes, Montgenèvre, 1800 m, VII, leg. M. Barták, ZMUM).

## TAXONOMIC REMARKS CONCERNING THE *CHAMAEPSILA PALLIDA* GROUP

Frey (1925) attempted to classify the species of *Chamaepsila* into more or less homogenous, "natural" groups based on their chaetotaxy. His "Gruppe 3", here called *Chamaepsila pallida* group, is characterized by the presence of 3 vertical setae, 2 dorsocentral setae posterior the suture and 1 well-developed postocellar seta. Body colour varies from almost entirely black (*Ch. rosae* subgroup, including *Ch. confusa*, *Ch. humeralis*, *Ch. nigricornis*, *Ch. persimilis*, *Ch. rosae*) to partly yellow and partly black (*Ch. pectoralis* subgroup with *Ch. pectoralis* and *Ch. strigata*) to almost entirely yellow (*Ch. pallida* subgroup). The latter subgroup is taxonomically the most difficult one. The following seven species which are recognized here as valid are assigned to this subgroup: *Ch. andreji* (Shatalkin, 1996), *Ch. luteola* (Collin, 1944), *Ch. nigrosetosa* Frey, 1925, *Ch. ozerovi* (Shatalkin, 1993), *Ch. pallida* (Fallén, 1820), *Ch. triorbiseta* Papp, 2003, and *Ch. unilineata* (Zetterstedt, 1847). Two of these species, *Ch. nigrosetosa* and *Ch. unilineata*, are subject to various interpretations by different students of the family and their status is revised here based on the study of additional specimens.

*Chamaepsila nigrosetosa* was described from one female from Finland. Hennig (1941) considered it as a colour morph of *Ch. pallida*, and Soós (1984) followed this interpretation. However, it differs from the latter clearly in several external characters and this may be the reason why it was recognized as a good species in the recent checklist of Diptera of Czech and Slovak Republics (Barták & Carles-Tolrá, 2006) and in the Fauna Europaea database (Pape, 2007).

The status of *Ch. unilineata* was often questioned in the past, and it was usually treated as a colour form of *Ch. pallida* (see above, under this species). Zetterstedt (1847) provided a rather good description which allows to differentiate it from the other species of *Chamaepsila* known at that time, especially from *Ch. pallida*. Unfortunately, Wang (1988) in her revision of the West Palaearctic *Chamaepsila*, dissected only one male of the "typical" *Ch. pallida*, but none of the form with black stripes ("*Ch. unilineata*") and she treated *Ch. unilineata* as a variety of *Ch. pallida* in the key. On the other hand, Barták & Carles-Tolrá (2006) and Pape (2007) considered both species as valid. It should be mentioned here that Séguy (1934) distinguished the two species in his key, one as *Ch. pallida*, the other as *Ch. debilis* (Egger, 1862). From his descriptions it is evident that his "*Ch. debilis*" corresponds with the original description of *Ch. unilineata*. He thought to follow basically the interpretation of Schiner (1863) who included the two species (*pallida* and *debilis*) in his key of Austrian Diptera. However, the description of "*Psila debilis*" sensu Schiner corresponds better with the current interpretation of *Ch. nigrosetosa* than of *Ch. unilineata* (which was diagnosed by Schiner in a footnote). The problems concerning the status of *Ch. unilineata* may be explained by the high variability of its external characters, in particular the development of the longitudinal, black, narrow stripes on the mesonotum which may be conspicuous, faint or absent (see "Material" above under *Ch. unilineata*). However, based on a careful study of numerous specimens it is concluded here that both species are valid and may be separated based on a combination of external and genitalian characters. In order to facilitate identification, an updated key for species of the *Ch. pallida* group is provided here.

## A SHORT KEY TO SPECIES OF THE EUROPEAN SPECIES OF THE *CHMAE - PSILA PALLIDA* GROUP

This key is based basically on external characters. Illustrations of the male terminalia may be found in Shatalkin (1986) and Wang (1988) for most species described until then and in the original descriptions for the species described since then. The species marked with an asterisk (*) were studied by us. The other species were included in the key based on their original descriptions.

1a Mesonotum entirely yellow . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2
1b Mesonotum yellow with black stripes or entirely black . . . . . . . . . . . . . . . . . 7
2a Subscutellum yellow. Arista short setulose, rays shorter than basal diameter of arista . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3
2b Subscutellum brown or black at least medially. Arista long setulose, rays longer than basal diameter of arista (see Hennig 1941, fig. 19, right illustration) . . . . . . . . . . . *Chamaepsila unilineata* (Zetterstedt, 1847) partim*
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . (= *Ch. pallida* auct. nec. Fallén)

3a Abdominal tergites black, Palpus apically black . . . . . . . . . . . . . . . . . . . . . . . 4
3b Abdominal tergites yellow. Palpus yellow, or narrowly brownish apically . . . 6
4a 3 fronto-orbital setae present. Frons yellow, with a transverse black stripe dorsally the lunule. Body length: 3.45 mm. - Hungary . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Chamaepsila triorbiseta* Papp, 2003
4b 1-2 fronto-orbital setae present. Frons yellow throughout . . . . . . . . . . . . . . . . 5
5a Postpedicel black. Setae on head and thorax ranging from yellow (specimens from the Caucasus) to dark brown (specimens from Northern Italy). Body length: 3.3 mm. - Russia (Caucasus), Italy . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Chamaepsila andreji* (Shatalkin, 1996)*
5b Postpedicel mainly yellow, with a darkened dorsal margin. Setae on head and thorax black. Body length: 4.5 mm. - Finland, Czech and Slovak Republics, Russia (Moscow area) . . . . . . *Chamaepsila nigrosetosa* Frey, 1925*
6a Postpedicel yellow. Setae on head and thorax light yellow. Body length: 4.0-5.0 mm. - Europe, Mongolia (?) . . . . *Chamaepsila pallida* (Fallén, 1820)*
6b Postpedicel mainly yellow, with a darkened dorsal margin. Palpus often narrowly brownish apically. Setae on head and thorax brownish yellow. Body length: 4.0 mm. - Great Britain, Denmark, Czech and Slovak Republics, Russia (Moscow area) . . . . . . . *Chamaepsila luteola* (Collin, 1944)*
7a Mesonotum yellow, with 3 longitudinal stripes. Pleuron yellow. Postpedicel mainly yellow, sometimes with a darkened dorsal margin. Arista long setulose, rays longer than basal diameter of arista (see Hennig 1941, fig. 19, right illustration). Male: Aedeagus narrow and paramere with four large teeth (figs 6-7). Body length: 4.0-5.0 mm - Europe . . . . . . . . . . . . . . . *Chamaepsila unilineata* (Zetterstedt, 1847) partim*
7b Mesonotum entirely black. Other characters variable . . . . . . . . . . . . . . . . . . . 8
8a Pleuron black, or black with a yellowish spot dorsally the anterior spiracle . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
8b Pleuron partly or entirely yellow, at least postpronotal lobe yellow . . . . . . . . 12
9a Pleuron with a yellowish spot dorsally the anterior spiracle. Praelabrum yellow . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 10
9b Pleuron entirely black. Praelabrum black . . . . . . . . . . . . . . . . . . . . . . . . . . . 11
10a Palpus yellow, rarely brownish infuscated. Postpedicel black but yellow ventrally at base. Male: terminalia as in figs 4-5. Body length: 3.5-3.8 mm. - Europe . . . . . . . . . . . . . . . *Chamaepsila persimilis* (Wakerley, 1959)*
10b Palpus black in apical half. Postpedicel entirely black. Male: terminalia as in fig. 1. Body length: 3.7-4.2 mm. - France, Switzerland . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ***Chamaepsila confusa* sp. n.***
11a Postpedicel black, but with a small yellow spot dorsally at base around and/or basally the insertion of the arista. Body length: 3.2-3.8 mm. - Holarctic species . . . . . . . . . . . . . . . . . . *Chamaepsila rosae* (Fabricius, 1794)*
11b Postpedicel entirely black. Body length: 3.4-4.2 mm. - Palaearctic, Oriental (Myanmar), Afrotropical (Kenya?) Regions . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *Chamaepsila nigricornis* (Meigen, 1826)*

12a Pleuron black, but postpronotal lobe (always) and sometimes also anepimeron yellow. Body length: 2.8-3.7 mm. - Europe ............ .......................... *Chamaepsila humeralis* (Zetterstedt, 1847)*
12b At least ventral half of pleuron yellow ............................ 13
13a Pleuron entirely yellow. Body length: 2.7-3.2 mm. - Europe ......... ............................ *Chamaepsila pectoralis* (Meigen, 1826)*
13b Pleuron bicoloured, dorsal half black, ventral half yellow. Body length: 3.0 mm. - Montenegro ................ *Chamaepsila strigata* (Collin, 1959)

## CONCLUSIONS

The present paper summarizes the present knowledge of the family Psilidae for Switzerland and discusses some taxonomical problems related to the European fauna. Up to 1998 reliable data for 6 species only were published from Switzerland (Ringdahl, 1957). They were all discovered after 1990 again. Whereas 32 species have been recorded from Switzerland in the checklist and its first supplement (Merz, 1998; Merz *et al.*, 2002), another 4 species are added here including two species new to science. Currently, 36 species are known with certitude from this country. Based on the checklists of other Central European countries (Germany, the Netherlands, Czech and Slovak Republics, Hungary) and our knowledge of the general distribution of the species it may be expected that another 6 species at least may be found with more extensive field work focused on this family. They are often either rare in collections, they have been overlooked due to their similarity with common species, or they were misidentified by non-expert entomologists. This list of expected species comprises *Chamaepsila andreji* (Shatalkin, 1996), *Ch. clunalis* (Collin, 1944), *Ch. luteola* (Collin, 1944), *Ch. rozkosnyi* Carles-Tolrá, 1993, *Ch. rufa* (Meigen, 1826), and *Ch triorbiseta* Papp, 2003. For instance, *Ch. andreji* and *Ch. rozkosnyi* were recently discovered in Northern Italy less than 50 km from the Swiss border, *Ch. clunalis* and *Ch. luteola*, both described from Great Britain, have a large distribution in Europe, as it is the case for *Ch. rufa*. On the other hand, *Ch. triorbiseta* was described few years ago from a single female only. It seems to be a rare species and may require special collecting techniques. The peculiar geographical position of Switzerland in the center of Europe with influences from various climatic areas allowed the occurrence of a diverse fauna with elements from different parts of Europe. The following three major elements constitute the Psilidae fauna of Switzerland. The largest number is represented by species which have a large distribution in Europe or even the entire Palaearctic Region (for instance, *Chamaepsila nigricornis*, *Ch. rosae*, *Psila fimetaria*). The second element comprise boreal and subarctic species of higher altitudes (generally the Alps) in Switzerland, like the two species of *Psilosoma*, *Chamaepsila atra*, or *Ch. morio*. Finally, *Chamaepsila sardoa* is recorded here for the first time from Southern Switzerland which represents the northernmost record of this Mediterranean element.

A new insight into some difficult species groups of *Chamaepsila* is presented here. In particular, the status of *Ch. unilineata* is revised based on numerous specimens from Switzerland. They allow to conclude that it is a good species clearly different from *Ch. pallida* with which it was usually synonymized. An updated key should permit to identify this and the other species of the *Ch. pallida* group with more confi-

dence. However, additional work is needed in order to understand fully the taxonomy of the difficult genus *Chamaepsila*. In particular, the study of some types should allow to fix the status of some of the enigmatic species which are known from few specimens or the type series only.

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## REFERENCES

Barták, M. & Carles-Tolrá, M. 2006. Psilidae Loew, 1861. *In*: Jedlicka, L., Stloukalová, V. & Kudela, M. (eds). Checklist of Diptera of the Czech Republic and Slovakia. *Bratislava, Comenius University*. Accessible at: http://zoology.fns.uniba.sk/diptera (accessed 2 May 2010).

Buck, M. & Marshall, S. A. 2006a. The identity of *Pseudopsila*, description of new subgenus of *Psila*, and redefinition of *Psila* sensu lato (Diptera: Psilidae). *European Journal of Entomology* 103: 183-192.

Buck, M. & Marshall, S. A. 2006b. Revision of New World *Loxocera* (Diptera: Psilidae), with phylogenetic redefinition of Holarctic subgenera and species groups. *European Journal of Entomology* 103: 193-219.

Carles-Tolrá, M. 1993a. A new species of *Chamaepsila* Hendel from the Czech Republic, with a key to the *bicolor*-group species (Diptera: Psilidae). *Graellsia* 49: 91-95.

Carles-Tolrá, M. 1993b. Two new species of Psilidae and Tethinidae from Spain. *Bollettino della Società Entomologica Italiana, Genova* 124(3) (1992): 250-253.

Chandler, P. J. 1975. Observations on plant associations of the Psilidae. *Entomological Records and Journal of Variation* 87: 13-17.

Chandler, P. J. 1998a. Psilidae (pp. 118-119). *In*: Chandler, P. J. (ed.). Checklists of Insects of the British Isles (New Series). Part 1: Diptera. *Handbooks for the Identification of British Insects* 12: 1-234.

Chandler, P. 1998b. Case 3068. *Musca rosae* Fabricius, 1794 (currently *Psila* or *Chamaepsila rosae* (Insecta, Diptera): proposed conservation of the specific name. *Bulletin of Zoo - logical Nomenclature* 55(2): 96-98.

Collin, J. E. 1944. The British Species of Psilidae (Diptera). *Entomologist's Monthly Magazine* 80: 214-224.

De Meijere, J. C. H. 1940. Über die Larven der in Orchideen minierenden Dipteren. *Tijdschrift voor Entomologie* 83: 122-127.

De Meijere, J. C. H. 1941. Pupariën van *Loxocera* in stengels van *Juncus*. *Entomologische Berichten Amsterdam* 10: 286-287.

Dengler, K. 1997. Zur Lebensweise von *Chyliza leptogaster* Panzer und *Ch. nova* Collin (Psilidae, Diptera) und ihre Bedeutung als Urheber von Bastnekrosen an Laubbäumen. *Studia Dipterologica* 4(1): 143-164.

EVENHUIS, N. L. 1989. 59. Family Psilidae (p. 473). *In*: EVENHUIS, N. L. (ed.). Catalog of the Diptera of the Australasian and Oceanian Regions. *Bishop Museum Press, Honolulu & E. J. Brill, Leiden*, 1155 pp.

FALLÉN, C. F. 1820. Opomyzides Sveciae. *Lundae*, 12 pp.

FERRAR, P. 1987. A Guide to the Breeding Habits and Immature Stages of Diptera Cyclorrhapha. *Entomonograph* 8(1): 1-478.

FREIDBERG, A. & SHATALKIN, A. I. 2009 (2008). The Psilidae (Diptera) of Israel, with emphasis on the *Chamaepsila hebraica* group. *Israel Journal of Entomology* 38 (2008): 35-60.

FREY, R. 1925. Zur Systematik der paläarktischen Psiliden (Dipt.). *Notulae entomologicae* 5: 47-50.

FREY, R. 1955. Studien über ostasiatische Dipteren V. Psilidae, Megamerinidae. *Notulae entomologicae* 35: 122-137.

GREVE, L. & MIDTGAARD, F. 1989. The genus *Chyliza* (Dipt., Psilidae) in Norway. *Fauna Norvegica (Serie B)* 36: 139-140.

GREVE, L. & SKARTVEIT, J. 2000. The genus *Loxocera* (Diptera, Psilidae) in Norway. *Norwegian Journal of Entomology* 48: 329-334.

GRICHANOV, I. Y., OVSYANNIKOVA, E. I., SAULICH, M. I. & SHATALKIN, A. I. 2005. Area and zone of harmfulness of *Chamaepsila rosae* (Fabr.) (Diptera, Psilidae). *Vestnik zashchity rastenii (Plant Protection News) (Saint-Petersburg-Pushkin)* 1: 73-75 (in Russian).

HENDEL, F. 1917. Beiträge zur Kenntnis der acalyptraten Musciden. *Deutsche entomologische Zeitschrift* 1917: 33-47.

HENDEL, F. 1934. Schwedisch-chinesische wissenschaftliche Expedition nach den nordwestlichen Provinzen Chinas. 13. Diptera. 5. Muscaria holometopa. *Arkiv för zoologi B* 25 A(21) (1933): 1-18.

HENNIG, W. 1941. 41. Psilidae. *In*: LINDNER, E. (ed.). Die Fliegen der Palaearktischen Region. Volume 5, Lieferung 140. *Schweizerbart'sche Verlagsbuchhandlung, Stuttgart*, 38 pp.

HOOPER, L. R. E., DIXON, P. L. & LARSON, D. J. 2002. Distribution and seasonal activity of adult carrot rust flies (Diptera: Psilidae). *The Canadian Entomologist* 134(5): 703-706.

ICZN (INTERNATIONAL COMMISSION OF ZOOLOGICAL NOMENCLATURE). 1999. Opinion 1938. *Musca rosae* Fabricius, 1794 (currently *Psila* or *Chamaepsila rosae*; Insecta, Diptera): specific name conserved. *Bulletin of Zoological Nomenclature* 56(3): 216-217.

IWASA, M. 1998. 3. 11. Family Psilidae (pp. 177-183). *In*: PAPP, L. & DARVAS, B. (eds). Contributions to a Manual of Palaearctic Diptera. Volume 3. *Science Herald, Budapest*, 880 pp.

IWASA, M., HANADA, T. & KAJINO, Y. 1987. A new psilid species from Japan injurious to the root of carrot (Diptera: Psilidae). *Applied entomology and zoology* 22(3): 310-315.

JOHNSON, C. W. 1920. A revision of the species of the genus *Loxocera*, with a description of a new allied genus and a new species. *Psyche* 27: 15-19.

LYNEBORG, L. 1964. Danske acalyptrate fluer. 2. Psilidae, Platystomidae og Otitidae (Diptera). *Entomologiske Meddelelser* 32: 367-388.

LYNEBORG, L. 1987. On the life history of *Chyliza annulipes* Macquart, 1835 (Diptera: Psilidae). *Entomologiske Meddelelser* 55: 27-29.

MCALPINE, D. K. 1997. Gobryidae, a new family of Acalyptrate flies (Diptera: Diopsoidea), and a discussion of relationships of the Diopsoid families. *Records of the Australian Museum* 49: 167-194.

MELANDER, A. L. 1920. Synopsis of the dipterous family Psilidae. *Psyche* 27: 91-101.

MERZ, B. 1998. 58. Psilidae (pp. 238-239). In: MERZ, B., BÄCHLI, G., HAENNI, J.-P. & GONSETH, Y. (eds). Diptera – Checklist. *Fauna Helvetica* 1: 1-369.

MERZ, B. & HAENNI, J.-P. 2000. 1.1. Morphology and terminology of adult Diptera (other than terminalia) (pp. 21-51). *In*: PAPP, L. & DARVAS, B. (eds). Contribution to a Manual of Palaearctic Diptera. Volume 1. *Science Herald, Budapest*, 978 pp.

MERZ, B., BÄCHLI, G. & HAENNI, J.-P. 2002. Erster Nachtrag zur Checkliste der Diptera der Schweiz. *Mitteilungen der Entomologischen Gesellschaft Basel* 51(3/4) (2001):110-140.

MERZ, B., BÄCHLI, G. & HAENNI, J.-P. 2007. Zweiter Nachtrag zur Checkliste der Diptera der Schweiz. *Mitteilungen der Entomologischen Gesellschaft Basel* 56(4) (2006): 135-165.

NARITA, O., OIKAWA, K., SATOH, M. & FUJIMURA, T. 2005. Occurrence of *Psila* (*Synaphopsila*) *nartshukae* (Diptera: Psilidae) injurious to roots of carrot in Aomori Prefecture. *Annual Report of the Society of Plant Protection of North Japan* 56: 134-136.

PAPE, T. 2007. Fauna Europaea: Psilidae. *In*: PAPE, T. (ed.). Fauna Europaea: Diptera, Brachycera. Version 1.3. *http://www.faunaeur.org* (accessed 8 May 2010).

PETIT, J. 1982. Chronique de la Montagne Saint-Pierre IX. Un orchidophile peu ordinaire: *Chyliza vittata* Meigen (Diptères, Psilidés). *Revue verviétoise d'histoire naturelle* 39: 61-64.

RINGDAHL, O. 1957. Fliegenfunde aus den Alpen. *Entomologisk Tidskrift* 78: 115-138.

SCHACHT, W. 1996. Zweiflügler aus Bayern X (Diptera: Pseudopomyzidae, Micropezidae, Tanypezidae, Megamerinidae, Psilidae). *Entomofauna* 17(14): 264-268.

SCHINER, J. R. 1863. XXI. Fam. Muscidae. XVII. Abtheilung. Psilinae (pp. 196-207). *In*: Die Fliegen (Diptera). Fauna Austriaca. Volume 2. *Wien*, XXXII & 658 pp.

SÉGUY, E. 1934. Diptères (Brachycères) (Muscidae Acalypterae et Scatophagidae). *Faune de France* 28: IV & 832 pp.

SÉGUY, E. 1936. Voyage de MM. L. Chopard et A. Méquignon aux Açores (août-septembre 1930). X. Diptères. *Annales de la Société entomologique de France* 105: 11-26.

SHATALKIN, A. I. 1983. New species of flies of the family Psilidae (Diptera) from the Far East. *Entomologicheskoe obozrenie* 62: 360-366 (in Russian).

SHATALKIN, A. I. 1986. Review of the eastpalaearctic flies of *Psila* Mg. (Diptera, Psilidae), with the key of the Palaearctic species. *Trudy Zoologicheskogo Instituta AN SSSR*, Leningrad 146: 23-43 (in Russian).

SHATALKIN, A. I. 1989. Notes on the Palaearctic Psilidae (Diptera). *Archives of the Zoological Museum of the Moscow State University* 27: 88-113 (in Russian).

SHATALKIN, A. I. 1998. Asian species of *Loxocera* Meigen (Diptera: Psilidae). *Russian Entomological Journal* 6(3-4) (1997): 87-97.

SHATALKIN, A. I. 2001. Afrotropical Psilidae (Diptera). 1. Genera *Belobackenbardia* gen. n. and *Psila* Meigen, 1803. *Russian Entomological Journal* 10(4): 417-424.

SHATALKIN, A. I. 2008. East Palaearctic and Oriental flies of the genus *Psila* Meigen (Psilidae). *Archives of the Zoological Museum of the Moscow State University* 49: 48-69 (in Russian).

SHTAKEL'BERG, A. A. 1989. 57. Family Psilidae (pp. 184-191). *In*: BEI-BIENKO, G. YA. (ed.). Diptera and Siphonaptera. *Keys to Insects of the European Part of the USSR*. Volume V. Part 2, XXII & 1505 pp.

SOÓS, Á. 1974. Taxonomische und faunistische Untersuchungen über die Psiliden (Diptera) aus der Mongolei. *Annales Historico-Naturales Musei Nationalis Hungarici* 66: 241-250.

SOÓS, Á. 1982. Untersuchungen des Typenmaterials der Rondani'schen Sammlung. 1. Psilidae (Diptera). *Folia Entomologica Hungarica* 43(1): 155-158.

SOÓS, Á. 1984. Family Psilidae (pp. 28-35). In: SOÓS, Á. & PAPP, L. (eds). Micropezidae-Agromyzidae. Catalogue of Palaearctic Diptera. Volume 9. *Akadémiai Kiadó, Budapest*, 460 pp.

SOÓS, Á. 1985. Untersuchungen einiger Psilide-Typen aus der Zetterstedt'schen Sammlung nebst Beschreibung einer neuen Art (Diptera: Psilidae). *Acta Zoologica Hungarica* 31: 235-244.

STEYSKAL, G. C. 1987. 60. Psilidae (pp. 781-784). *In*: MCALPINE, J. F., PETERSON, B. V., SHEWELL, G. E., TESKEY, H. J., VOCKEROTH, J. R. & WOOD, D. M. (eds). Manual of Nearctic Diptera. Volume 2. *Research Branch, Agriculture Canada, Monograph* 28: 675-1332.

THOMPSON, F. C. & PONT, A. C. 1994. Systematic database of *Musca* names (Diptera). *Theses Zoologicae* 20: 1-219.

VAN DER GOOT, V. S. & VAN VEEN, M. P. 1996. De Spillebeenvliegen, Wortelvliegen en Wolzwevers van Noordwest-Europa. *Jeudbondsuitgeverij, Utrecht*, 57 pp.

VERNON, J. D. R. 1962. Observation on the biology and control of the *Chrysanthemum* stool miner. *Plant Pathology* 11(1): 38-40.

WAKERLEY, S. B. 1959. A new species of *Psila* Meigen (Diptera: Psilidae) from Northern England. *Proceedings of the Royal entomological Society of London* (B) 28(7-8): 107-108.

WANG, X. 1988. Bestimmungstabellen der westpaläarktischen *Chamaepsila*-Arten (Diptera: Psilidae). *Stuttgarter Beiträge zur Naturkunde*, Serie A 417: 1-13.

WANG, X. & YANG, C. 1996. Psilidae (pp. 424-456). In: XUE, W. & CHAO, CH. (eds). Flies of China. Volume 1. *Liaoning Science and Technology Press, Shenyang*: 1-1365.

YANG, C. & WANG, X. 1988. A new species of *Chyliza* (Psilidae: Diptera) from China, injuring bamboo roots. *Forest Research* 1: 275-277.

ZETTERSTEDT, J. W. 1860. Diptera scandinaviae disposita et descripta. Volume 14. *Lundae*, 6191-6609.

## APPENDIX

### A REVISED CHECKLIST OF THE PSILIDAE OF SWITZERLAND

The following abbreviations are used behind the names: N = New record for Switzerland in the present paper; R1 = Merz (1998); R2 = Merz *et al.* (2002)

SUBFAMILY CHYLIZINAE

***Chyliza*** Fallén, 1820
- *annulipes* Macquart, 1835 R1
- *extenuata* (Rossi, 1790) R1
- *leptogaster* (Panzer, 1798) R1
- *nova* Collin, 1944 R1
- *vittata* Meigen, 1826 R1

SUBFAMILY PSILINAE

Tribe Loxocerini

***Imantimyia*** Frey, 1925
- *albiseta* (Schrank, 1803) R1
- *fulviventris* (Meigen, 1826) R1
- *nigrifrons* (Macquart, 1835) R1
- *sylvatica* (Meigen, 1826) R1

***Loxocera*** Meigen, 1803

subgenus ***Loxocera*** Meigen, 1803
- *aristata* (Panzer, 1801) R1
- *maculata* Rondani, 1876 R2

subgenus ***Platystyla*** Macquart, 1835
- *hoffmannseggi* Meigen, 1826 R1

Tribe Psilini

***Chamaepsila*** Hendel, 1917
- *atra* (Meigen, 1826) R1
- *bicolor* (Meigen, 1826) R1
- *buccata* (Fallén, 1826) R1
- *confusa* Shatalkin & Merz, sp. n. N
- *humeralis* (Zetterstedt, 1847) R1
- *limbatella* (Zetterstedt, 1847) R1
- *morio* (Zetterstedt, 1835) R1
- *nigra* (Fallén, 1820) R1
- *nigricornis* (Meigen, 1826) R1
- *obscuritarsis* (Loew, 1856) R1
- *pallida* (Fallén, 1820) R1
- *pectoralis* (Meigen, 1826) R1
- *persimilis* (Wakerley, 1959) R1
- *quadrilineata* (Strobl, 1898) R1
- *rosae* (Fabricius, 1794) R1
- *sardoa* (Rondani, 1876) N
- *unilineata* (Zetterstedt, 1847) N
- *villosula* (Meigen, 1826) R1

***Psila*** Meigen, 1803

subgenus ***Oxypsila*** Frey, 1925
- *abdominalis* Schummel, 1844 R1

subgenus ***Psila*** Meigen, 1803
- *fimetaria* (Linnaeus, 1761) R1
- *helvetica* Shatalkin & Merz, sp. n. N
- *merdaria* Collin, 1944 R1

***Psilosoma*** Zetterstedt, 1860
- *audouini* (Zetterstedt, 1835) R1
- *lefebvrei* (Zetterstedt, 1835) R1

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# An annotated list of type material of Orthoptera (Insecta) described by Achille Griffini and deposited in the collections of the Muséum d'histoire naturelle in Geneva.

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**An annotated list of type material of Orthoptera (Insecta) described by Achille Griffini and deposited in the collections of the Muséum d'histoire naturelle in Geneva. -** Primary types of ten species have been located in the collections of the Muséum d'histoire naturelle in Geneva (MHNG). The status of specimens of two other species which are labelled as types is discussed. The names are listed alphabetically, and the sex, label data and condition of the specimens is given, along with their location within the collections, and the current nomenclatural combination.

**Keywords:** A. Griffini – Tettigoniidae - Stenopelmatoidea – Gryllacrididae – Anostostomatidae – type catalogue.

## INTRODUCTION

Achille Griffini (1870-1932) was a prolific Italian entomologist specialising in the Orthoptera, and more particularly the Stenopelmatoidea. He worked as assistant in the Turin Museum of Natural History (Italy), and most of his collection is there or in Giacomo Doria Museum of Natural History in Genoa. Griffini studied most of the Stenopelmatoidea present in the MHNG collections and described a number of species based on this material. In the descriptions he states how many specimens he saw and which gender they were. However, his use of the term "type" does not correspond to that currently recognised, which has led to some confusion. Primary types of ten species are present in the MHNG collections, while a further two species are erroneously labelled as types.

## ARRANGEMENT AND FORMAT

The species are listed alphabetically. The format for each is:

***species name*** Author, work: page [*Original generic placement*].

Number of specimens. Specimen: "Label data" [format of label]. Following the recommendations of Ohl & Oswald (2004) the condition of each specimen is noted, although damage to the tips of the antennae or wear to wing margins is not enumerated. Other comments. Location of material in the MHNG main Orthoptera collection.

Currently valid binomen of taxon (according to OSF).

The abbreviation OSF refers to *Orthoptera Species File Online* (Eades & Otte, 2010).

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## CATALOGUE

***basaliatrata*** Griffini, 1909b: 384 [Gryllacris].

One ♂ and one ♀ specimen. A ♂ with labels: "Captain Balber, Naga-H." [name handwritten and locality printed on white card]; "1857" [handwritten on white paper]; "Gryllacris atrata Br. ♂" [handwritten on yellow paper]; "Gryllacris basaliatrata Griffini ♂" [handwritten by Griffini on ruled white card]; "Griffini, Type" [name handwritten on pink, printed card]. Specimen set with left wings spread and right wings folded; most of the left antenna is missing, as is the right middle leg. A ♀ with labels: "Capt. Balb., Naga-H." [name handwritten and locality printed on white card]; "18" [handwritten on white paper]; "Gryllacris atrata Brunn." [handwritten on white paper]; "Gryllacris atrata Br. ♀" [handwritten on yellow paper]; "Gryllacris basaliatrata Griffini ♀" [handwritten by Griffini on ruled white card]; "Griffini, Type" [name handwritten on pink, printed card]. Specimen set with right wings spread and left wings folded; both middle legs and the left hind leg are lost. Because *G. basaliatrata* is a replacement name for *G. basalis* Kirby, 1906 (itself a replacement name for *G. atrata* Brunner von Wattenwyl, 1888), the specimens designated as types by Griffini in the MHNG collection are not part of the type series, notwithstanding the labels. Box N1.

*Diaphanogryllacris basaliatrara* (Griffini, 1909).

***bedoti*** Griffini, 1909b: 381 [*Gryllacris*].

Holotype ♀ with labels: "Gryllacris Bedoti Griffini, Typus! ♀" [handwritten by Griffini on ruled white card]; "voisin de Gryllacris punicea Gerst." [handwritten on pink paper]; "Griffini, Type" [name handwritten on printed pink card]; "Holotypus" [printed on red card]. The species name label in the insect box has the locality "Madagascar" written in the lower left corner. Specimen set with left wings spread and right wings folded; the right antenna is lost, the left front leg lacks tibia and tarsi and the right front leg lacks the tarsi. Box N1.

*Pissodogryllacris bedoti* (Griffini, 1909).

***carli*** Griffini, 1911: 485 [*Anabropsis*].

Holotype ♂ with labels: "Tonkin, ach. Baudet" [printed on white paper]; "Anabropsis Carli, Griffini, ♂ Typus!" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded; the left hind leg lacks part of the last tarsal segment. Box O4.

*Paterdecolyus carli* (Griffini, 1911).

***indecisa pungens*** Griffini. 1911: 463 [*Gryllacris*].

Holotype ♀ with labels: "Saussure, Madagascar" [printed on white paper]; "Gryllacris indecisa Griff., var. pungens Griff., Typus! ♀" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded; most of both antennae are missing. Box N4.

*Niphetogryllacris pungens* (Griffini, 1911).

***kirbyi*** Griffini, 1912: 308 [*Spizaphilus*].

One ♂ and one ♀ syntype. A ♂ with labels: "Madagascar (Sikora), September 1894" [handwritten on white paper]; "*Spizaphilus kirbyi* Griffini, Typus! ♂" [hand-

written by Griffini on ruled white card]; "Syntypus" [printed on red paper]. Specimen set with right wings spread and left wings folded; the right middle leg is missing. A ♀ with labels: "Madagascar" [handwritten on white paper]; "*Spizaphilus kirbyi* Griffini, Typus! ♀" [handwritten by Griffini on ruled white card]; "Syntypus" [printed on red paper]. Specimen set with wings folded. Johns (1997) did not designate a lectotype. Box O5.

*Spizaphilus kirbyi* Griffini, 1912.

***laeta annamita*** Griffini, 1909a: 3 [*Gryllacris*].

One ♀ with labels: "Annam, Phuc-Son, Nov.-Dec., H. Fruhstorfer" [printed on whitecard]; "Gryllacris chinensis Brun." [handwritten on yellow paper]; "Musée de Genè ve, No 20" [number handwritten on printed white card]; "Gryllacris laeta Walker var. annamita Griffini ♀" [handwritten by Griffini on ruled white card]; "Griffini, Type" [name handwritten on printed pink card]. Specimen set with left wings spread and right wings folded; both antennae are missing. The left hind leg is detached and pinned through the femur on the original pin, it lacks two tarsal segments. This specimen is a "topotype" and probably part of the same series as the material acquired by D. Rolle from Fruhstorfer (now deposited in Turin) upon which Griffini based his description, but was not used for the original description (see Griffini 1909b) and so is not a syntype. Box N1.

*Diphanogryllacris annamita* (Griffini, 1909)

***maculipennis bakeri*** Griffini, 1915: 67 [*Gryllacris*].

Holotype ♀ with labels: "Manille" [printed on white paper]; "49" [handwritten on orange paper]; "Gryllacris maculipennis St." [handwritten on white card]; "Gryllacris maculipennis ♀ Stål" [handwritten on yellow paper]; "Musée de Genève, No 45" [number handwritten on printed white card]; "Gryllacris maculipennis Stål, ♀ var., (cum type comperata et descripta a Griffini)" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded. The specimen was described as a variety in Griffini's 1909b publication (as noted on the label), but only named in the 1915 publication. Box N3.

*Hemiandrus maculipennis bakeri* (Griffini, 1915).

***mannae*** Griffini, 1909b: 391 [*Gryllacris*].

Holotype ♀ with labels: "Madagascar, H. de Saussure" [printed on white paper]; "Gryllacris mannae Griffini, Typus! ♀" [handwritten by Griffini on ruled white card]; "Griffini, Type" [name handwritten on printed pink card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded; most of both antennae are missing and the right front leg lacks the tarsi. Box N3.

*Pissodogryllacris mannae* (Griffini, 1909).

***pattersonii brevimucronatus*** Griffini, 1911: 496 [*Henicus*].

Holotype ♂ with labels: "Newlands, Purcell" [handwritten on a strip of white card]; "Henicus Pattersoni (Stoll), subsp. Brevimucronatus Griffini, ♂ Typus!" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Most of the

right antenna, the right middle leg and the tibia and tarsi of the right hind leg are lost. Box O6.

*Henicus brevimucronatus* Griffini, 1911.

***saussurei*** Griffini, 1911: 463 [Gryllacris].

Holotype ♀ with labels: "H de Saussure, Madagascar" [printed on white paper]; "comp. laeta Br." [handwritten in pencil on white paper]; "Gryllacris saussurei ♀ Griffini, Typus!" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded; most of the left antenna is missing. Box N4.

*Pissodogryllacris saussurei* (Griffini, 1911).

***sharpi*** Griffini, 1898: 4 [*Cocconotus*].

One ♂ syntype with labels: "Ecuador" [handwritten on green paper]; "Rio Peripa" [handwritten on a strip of white paper]; "type" [handwritten on a strip of white card]; "Cocconotus sharpi ♂ Griff." [handwritten by Griffini on ruled white card]; "Bilastes (Cocconotus) sharpi Griff." [handwritten on green paper]; "Syntypus" [printed on red paper]. Specimen set with wings folded; most of the right antenna and the left hind leg are lost. Images on OSF. Box E23.

A junior synonym of *Tricentrus astrosignatus* (Brunner von Wattenwyl, 1895).

***silvestrii*** Griffini, 1911: 469 [*Gryllacris*].

Holotype ♀ with labels: "Saussure, Madagascar" [printed on white paper]; "vois. de conspersa Br." [handwritten in pencil on white paper]; "Gryllacris silvestrii ♂ [sic] Griffini, Typus!" [handwritten by Griffini on ruled white card]; "Holotypus" [printed on red card]. Specimen set with left wings spread and right wings folded; most of both antennae are missing. Box N4.

*Pissodogryllacris silvestrii* (Griffini, 1911).

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Thanks are due to Anita Hollier and Peter Schwendinger (MHNG) for comments on the layout and text. Bernd Hauser (MHNG) provided valuable information about the history of the collections.

## REFERENCES

Eades, D. C. & Otte, D. 2010. *Orthoptera Species File Online*. Version 2.0/3.5. Online at http://Orthoptera.SpeciesFile.org [Accessed 10.iii.2010].

Griffini, A. 1898. Sopra alcuni Grillidi e Loscutidi nuovi o poco noti. *Bollettino dei Musei di Zoologia ed Anatomia Comparata della R. Università di Torino* 13 (319): 1-7.

Griffini, A. 1909a. Di una varietà della *Gryllacris laeta* Walker e sopra un esamplare anomalo di questo. *Bollettino dei Musei di Zoologia ed Anatomia Comparata della R. Università di Torino* 23 (597): 1-14.

Griffini, A. 1909b. Studi sopra alcune *Gryllacris* del Museum d'histoire naturelle de Genève. *Revue suisse de Zoologie* 17: 374-404.

Griffini, A. 1911. Note intorno ad alcuni Grillacridi e Stenopelmatidi del Muséum d'histoire naturelle de Genève. *Revue suisse de Zoologie* 19: 461-500.

GRIFFINI, A. 1912. Il genere *Spizaphilus* Kirby e le sue specie. *Atti della Società Italiana de Sciense Naturali* 50: 303-314.

GRIFFINI, A. 1915. Prospetto dei Grillacridi delle Isole Filippine. *Philippine Journal of Science* 10: 61-71.

JOHNS, P. M. 1997. The Gondwanaland Weta: Family Anostostomatidae (formerly in Stenopelmatidae, Henicidae or Mimnermidae): Nomenclatural problems, world checklist, new genera and species. *Journal of Orthoptera Research* 6: 125-138.

OHL, M. & OSWALD, J. D. 2004. Annotated list of the primary type specimens of Megaloptera and Raphidioptera (Insecta, Neuropterida) in the Museum für Naturkunde der Humbolt-Universität zu Berlin. *Deutsche Entomologische Zeitschrift* (N.S.) 51: 87-96.

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# An annotated list of primary types of Orthoptera (Insecta) described by Boris Uvarov and deposited in the collections of the Muséum d'histoire naturelle in Geneva

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**An annotated list of primary types of Orthoptera (Insecta) described by Boris Uvarov and deposited in the collections of the Muséum d'histoire naturelle in Geneva.** - Primary types of ten species have been located in the collections of the Muséum d'histoire naturelle in Geneva (MHNG). The names are listed alphabetically, and the sex, label data and condition of the specimens is given, along with their location within the collections, and the current nomenclatural combination.

**Keywords:** B. Uvarov - Acridoidea - Acrididae - Pyrgomorphidae - type catalogue.

## INTRODUCTION

Boris Uvarov (1889-1970) was born and educated in Russia, but spent most of his career in Britain. He was one of the leading Orthopterists of the twentieth century, specialising particularly on the grasshoppers and locusts. Uvarov started work at the Imperial Bureau of Entomology in London in 1920, and soon became involved in work on locust outbreaks. His small team was already regarded as the leading research group in the field when the Anti-Locust Research Centre was formally created in 1945, with Uvarov as the director from its foundation until he retired in 1959 (Wigglesworth, 1971).

As a leading grasshopper specialist, and one with experience of the fauna of the Indian sub-continent (which was part of the British Empire at the time), Uvarov was the obvious choice to treat the Acridoidea material collected during the expedition of J. Carl (of the Muséum d'histoire naturelle in Geneva (MHNG)) and K. Escher to southern India in 1926-1927. As a consequence, many specimens in the MHNG collections have been identified by Uvarov, and he described twelve new species based on this material (Uvarov, 1929).

Primary types of ten Uvarov species have been located in the MHNG collections. Despite the introduction to his 1929 paper (treating the Carl & Escher material) stating that all of the [holo]types were in Geneva, in the descriptions of *Chitaura indica* and *Spathosternum abbreviatum* he actually says that the [holo]types are in the Natural History Museum in London, with only paratypes in the MHNG collections.

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## ARRANGEMENT AND FORMAT

The species are listed alphabetically. The format for each is:

***species name*** Author, work: page [*Original generic placement*].

Number of specimens. Specimen: "Label data" [format of label]. Following the recommendations of Ohl & Oswald (2004) the condition of each specimen is noted. Other comments. Location of material in the MHNG main Orthoptera collection.

Currently valid binomen of taxon (according to OSF).

The abbreviation OSF refers to *Orthoptera Species File Online* (Eades & Otte, 2010).

## CATALOGUE

***alata*** Uvarov, 1929: 540 [*Capulica*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Masnigudi, 29.I.27, Buschgras" [first two lines printed, specific locality handwritten on white card]; "Capulica alata sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen is in good condition; there are two £ labelled as paratypes. Box U16.

*Capulica alata* Uvarov, 1929.

***carinata*** Uvarov, 1929: 536 [*Carlia*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Tanakamalai, ob. & untere Grasstufe, 10.III" [first two lines printed, specific locality handwritten on white card]; "Carlia carinata, g. & sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen is in good condition; two ♂ and three ♀ specimens are labelled as paratypes. Box U9.

*Carliola carinata* (Uvarov, 1929).

***carli*** Uvarov, 1929: 551 [*Orthacris*].

Lectotype ♂ (designated by Singh & Kevan, 1965: 399) with labels: "Voy. Carl et Escher, Inde méridionale, Pollachi 20.II, Ebene! 200 m." [first two lines printed, specific locality handwritten on white card]; "Orthacris carli sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Lectotype des. Singh & Kevan, 1965" [handwritten on red paper]. The specimen is in good condition. Although this specimen was labelled as "type", there was no type designation in the original description and therefore all three specimens mentioned there were syntypes. A ♀ labelled as a paratype is actually a paralectotype. Box X6.

A junior synonym of *Neorthacris acuticeps* (Bolivar, 1902).

***collina*** Uvarov, 1929: 539 [*Zygophlaoeba*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Elkhill 14.I, sonn. W-halde, unter d. Gipfel" [first two lines printed, specific locality handwritten on white card]; "Zygophlaoeba collina sp. n., TYPE, Det. B. Uvarov 1929" [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red

card]. The specimen lacks the right middle leg; there are five ♀ labelled as paratypes. Box U14b.

*Zygophlaoeba collina* Uvarov, 1929.

***collinus*** Uvarov, 1929: 543 [*Aulacobothrus*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Masnigudi, 29.I.27, Buschgras" [first two lines printed, specific locality handwritten on white card]; "Aulacobothrus collinus sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen lacks the antennae and right front leg; the right hind leg is detached and pinned through the femur on the original pin. One ♂ and one ♀ are labelled as paratypes. Box U16.

A junior synonym of *Leiontacris bolivari* (Uvarov, 1921).

***escheri*** Uvarov, 1929: 549 [*Orthacris*].

Lectotype ♂ (designated by Singh & Kevan, 1965: 395) with labels: "Voy. Carl et Escher, Inde méridionale, Vandaravu, Palnis, 2300-2500 m." [first two lines printed, specific locality handwritten on white card]; "Orthacris escheri sp. n., TYPE, Det. B. Uvarov 1928." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on card disc with red margin]; "Lectotype des. Singh & Kevan, 1965" [handwritten on red paper]. The specimen has lost both antennae and all legs, dissected parts are placed in a small vial secured through the cork to the original pin. Although this specimen was labelled as "type", there was no type designation in the original description and therefore all three specimens mentioned there were syntypes. A ♀ labelled as a paratype is actually a paralectotype. Box X6.

A junior synonym of *Neorthacris palnensis* (Uvarov, 1929).

***medium*** Uvarov, 1929: 558 [*Spathosternum*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Masnigundi, trock. Busch, 29.I" [first two lines printed, specific locality handwritten on white card]; "Spathosternum medium sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen is in good condition; there is also a ♀ labelled as a paratype. Box Z20.

A junior synonym of *Spathosternum abbreviatum* Uvarov, 1929.

***nilgirensis*** Uvarov, 1929: 550 [*Orthacris*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Hill Grove, 22.XII.26, Nilgiris" [first two lines printed, specific locality handwritten on white card]; "Orthacris nilgirensis sp. n., TYPE, Det. B. Uvarov 1929" [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen is in good condition; another ♂ and two ♀ are labelled as paratypes. Box X6.

*Neorthacris acuticeps nilgirensis* (Uvarov, 1929).

***palnensis*** Uvarov, 1929: 548 [*Orthacris*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Tandikudi 25.IV, Lower Palnis" [first two lines printed, specific locality handwritten on white

card]; "Orthacris palnensis sp. n., Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on card disc with red margin]; "= Neorthacris palnensis (Uv.) Det. D. K. Mc E. Kevan, 19564" [determination and last two digits of date handwritten on white card with Kevan's name printed]. The antennae are missing and some dissected parts are placed in a small vial secured through the cork to the original pin. Box X6.

*Neorthacris palnensis* (Uvarov, 1929).

***rotundata*** Uvarov, 1929: 537 [*Phlaeoba*].

Holotype ♂ with labels: "Voy. Carl et Escher, Inde méridionale, Kodiakanal, 2000 m, Palnis, 15.IV" [first two lines printed, specific locality handwritten on white card]; "Phleoba rotundata sp. n., TYPE, Det. B. Uvarov 1929." [handwritten on white card with Uvarov's name and date printed]; "Holotypus" [printed on red card]. The specimen is in good condition; another ♂ is labelled as a paratype. Box U14.

*Phlaeoba rotundata* Uvarov, 1929.

As well as 1 ♂ and 2 ♀ paratypes of *Chitaura indica* Uvarov, 1929 (box Z19) and 1 ♂ and 1 ♀ paratypes of *Spathosternum abbreviatum* Uvarov, 1929 (box Z20), the MHNG collections contain a pair of paratypes (each with the distinctive round paratype labels of the Natural History Museum in London, and with a typed label "don du British Museum (Natural History)" ) of each of the following species: *Acorypha modesta* Uvarov, 1950 (box Z68); *Chorthippus ilkazi* Uvarov, 1934 (box U21); *Duroniella cooperi* Uvarov, 1943 (box U14b); *Duroniella laeviceps* Uvarov, 1938 (box U14b); *Eucoptacra brevidens* Uvarov, 1953 (box Z50); *Omocestis nanus* Uvarov, 1934 (box U21); *Paraschmidtia burri* (Uvarov, 1953) (box S3); *Staurocleis magnifica* Uvarov, 1923.

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## REFERENCES

EADES, D. C. & OTTE, D. 2010. *Orthoptera Species File Online*. Version 2.0/3.5. <http://Orthoptera.SpeciesFile.org> [Accessed 10.iii.2010].

OHL, M. & OSWALD, J. D. 2004. Annotated list of the primary type specimens of Megaloptera and Raphidioptera (Insecta, Neuropterida) in the Museum für Naturkunde der Humbolt-Universität zu Berlin. *Deutsche Entomologische Zeitschrift* (N.S.) 51: 87-96.

SINGH, A. & KEVAN, D. K. M. 1965. The genus *Orthacris* Bolivar, 1884, and its allies (Orthoptera; Acridoidea; Pyrgomorphidae). *Transactions of the Royal Entomological Society* 117: 367-416.

UVAROV, B. P. 1929. Acrididen (Orthoptera) aus Süd-Indien. *Revue suisse de Zoologie* 36: 533-563.

WIGGLESWORTH, V. B. 1971. Boris Petrovitch Uvarov. 1889-1970. *Biographical Memoirs of Fellows of the Royal Society* 17 : 713-740.

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# Nutritional ecology of *Microtus arvalis* (Pallas, 1779) in sown wild flower fields and quasi-natural habitats

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**Nutritional ecology of *Microtus arvalis* (Pallas, 1779) in sown wild flower fields and quasi-natural habitats.** - Recently, sown wild flower fields (SWFF) were established as ecological compensation areas to enhance and preserve animal and plant biodiversity. Besides their positive effects, SWFF can also shelter potential pest species, like *Microtus arvalis*, which stay preferentially in those fields. To analyse the nutritional ecology of *M. arvalis* in SWFF and in quasi-natural habitats, 100 voles were trapped in each habitat type near Bern, from October 2006 to July 2007. Stomach content and faecal pellets were examined microscopically. Ingested plant fragments were identified using reference slides. The ingested quantity of each plant was assessed according to the covered surface on a microscopic slide. Rank preference indices of Johnson were calculated by comparing food-composition with food-offer in the vegetation. The food spectrum was rather wide, including numerous grasses and herbs. Monocots constituted the main part in both habitats, although they were not as frequent in SWFF as dicots. Neither for monocots nor for dicots a clear preference was found. SWFF seem not to be the main reason for the frequent occurrence of *M. arvalis* in these areas. Further studies are needed to determine why common voles are attracted by the naturally growing grasses.

**Keywords:** diet analyses - food preference - sown wild flower fields - quasi-natural habitats

## INTRODUCTION

The intensification of agriculture has increased mainly in the second half of the 20th century. The impact of fertilizers and pesticides has considerably reduced the number and diversity of plant and animal species. As a consequence, natural and quasi-natural habitats for animals and plants were lost.

A change was initiated in the last decades through the reorientation of the agricultural policy, with ecological compensations areas (ECA) and with new goals related to structural improvements of the landscape. The focus is directed on the diversity of species, valuable habitats and attractive cultural landscapes. Therefore ECAs, such as extensively used meadows, sown wild flower areas (SWFF), hedges or fallow land, were established and associated with direct payments to the farmers. These areas should preserve and enhance biodiversity in agro-ecosystems.

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SWFF are part of these ECAs, which have been progressively introduced into the agricultural landscape during the last two decades (Nentwig, 2000). These habitats are sown with a seed mixture of about 30 native annual weeds and perennial ruderals. Since 1993 farmers receive subsidy from the Swiss government to maintain at least 7% of their farmland as ECAs. The farmers are not allowed to use chemical plant protection agents and fertilizers.

ECAs increase the diversity of flowers (Heitzmann & Nentwig, 1993) and the number of small mammals (Baumann, 1996) and birds (Lille 1996). Frank & Nentwig (1995) showed positive effects of SWFF on arthropod density. SWFF can also shelter animals, including small mammals, considered as pest species because these fields are left uncultivated for longer periods and therefore can serve as refuges for them. The common vole, *Microtus arvalis*, is such a potential agricultural pest species due to its high reproductive rate and its exclusive herbivorous nutrition. Population densities of more than 3000 individuals per hectare were reported (Truszkowski, 1982). Due to its high adaptability, the common vole has to be considered as a hemerophil animal, i.e. an animal taking advantage of the anthropogenic changes in the environment and following therefore humans into the cultural landscape (Leicht, 1979). SWFF, which are a part of the cultural landscape, offer high floral diversity and biomass (Heitzmann & Nentwig, 1993). Briner *et al.* (2005) showed that they are an appropriate habitat for the common vole.

Admittedly, the intensive agriculture and the loss of perennial grassland have decreased the density of the common vole as well. But the implementation of ECAs led to a new concern of farmers about the immigration of voles from SWFF into cropland. Furthermore, voles of the genus *Microtus* constitute the main part of the kestrel's and long-eared owl's diet (Aschwanden *et al.*, 2005) and common buzzards, foxes, stoats or weasels feed on voles as well (Niethammer & Krapp, 1982).

The nutritional ecology of *M. arvalis* in quasi-natural habitats has been investigated by Yu *et al.* (1980), Leutert (1983) and Rinke (1987, 1990, 1991). The study of Yu *et al.* (1980) done in France cannot be compared directly with the present one. Rinke (1990) worked in Germany. For Leutert (1983), the main focus was not food ecology but the effects of common vole on plant composition in meadows. Except for the work of Balmelli *et al.* (1999), in which choice-trials were conducted, no studies about food ecology of *M. arvalis* in SWFF are available.

The aim of the present study was to analyse the nutritional ecology of *M. arvalis* in SWFF compared to quasi-natural habitats. The main questions were: what kind of plant species are ingested in SWFF and in quasi-natural habitats, respectively. Furthermore, to what extent does the food intake differ in SWFF from that in quasi-natural habitats, particularly since in SWFF a large number of additional plants is available, which voles could possibly use as food resources? Does *M. arvalis* prefer sown wild flowers or does it feed on grasses and other forbs naturally growing in SWFF, but which are not contained in the seed mixture? If the typical plants of SWFF were eaten more often and in larger quantities, these plants could be a possible reason for the preferential occupation of SWFF. Conversely, if only few fragments of sown wild flowers can be detected in the diet, the reason for the high density of *M. arvalis* in such fields must be another one.

## MATERIAL AND METHODS

### Diet analysis in general

Several methods exist to investigate the nutritional ecology of a given organism. A first approach is the direct observation of an organism in the field.

Analysis of the stomach content has the advantage that the plant fragments are mostly well preserved, but the animals need to be killed (Batzli & Pitelka, 1983). Stomach analysis was favoured in the present study, because food items in the stomach are not exposed to gastric secretions as long as faecal samples and are therefore easier to identify.

A source of error in faecal and stomach analyses lies in the fact that not every plant fragment can be identified (Hansson, 1970). Only the epidermis has distinctive features and is therefore identifiable. The other ingested plant structures, like vascular bundles, roots, seeds, can hardly be assigned to a precise plant species. It is assumed that the ratio of unidentified food particles to identified epidermis material remains constant. Another potential source of error for both methods is the observer's bias. Even with an excellent reference collection, it is impossible to classify an ingested plant, if the relevant identification characteristic features are not observable under the microscope (Westoby *et al.*, 1976).

### Vegetation survey

Three SWFF (Grauholz [GH, 46°59'38" N, 7°29'03" E, 606 m], Niederwangen [NW, 46°55'41 N, 7°21'10" E, 655 m], Uettligen [UE, 46°58'37" N, 7°22'42" E, 576 m]) and three quasi-natural habitats (Riedbach [RB, 46°56'24" N, 7°19'31" E, 565 m], Hinterkappelen [HK, 46°58'19" N, 7°22'35" E, 566 m], Moosseedorf [MD, 47°00'43" N, 7°28'34", 545 m]) were chosen as study areas. In each site, the vegetation was mapped and recorded in mid October and March and at the beginning of June on five subplots of one $m^2$ and along the trapping line, because common voles generally graze on their paths (Stein 1958). Only vegetation structures below 80 cm were considered. All plant species were identified (Eggenberg & Möhl, 2007, Eggenschwiler & Jacot, 2001, Lauber & Wagner, 2001) and the cover index ranged from 1 to 5, according to Braun-Blanquet (1964) (1 = cover 1-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-100%). The results of the five subplots were averaged to get the total cover for each plant species within one plot and are expressed in percent, representing the availability of the plants for an animal.

### Trapping

A total of 200 *M. arvalis* were captured in Longworth live traps from October 2006 to July 2007 in the six plots. Hundred voles were trapped in the three SWFF and in the three quasi-natural habitats, respectively. First of all, the habitats were scanned for signs of vole presence. Then the traps were placed in the middle of the habitat with a buffer zone of at least 10 m in sown wild flower fields on each end and 2 m in the quasi-natural habitats according to the size of the fields. The traps were placed in one line at a distance of 1-2 m between them, depending on the frequency of activity signs of *M. arvalis*, i.e. holes, food remains, feeding places, droppings or pathways. The nest box of the traps was filled with dry hay for bedding; cheese, pieces of apple and

hamster food served as bait. Normally 32 traps per habitat were used. They remained open at night to enhance the trapping success. Nineteen animals, or 9.5%, died in the traps, but it was still possible to analyse the stomach contents or the droppings. The traps were checked once a day, but twice when the weather was hot or very cold. All animals caught were killed using carbon dioxide and put in a plastic bag with a label. Some faecal pellets found in the traps were also collected to get enough material in case the stomach was empty (Putman, 1984). In the laboratory the voles and pellets were deep frozen for better conservation.

### Laboratory analysis

In the laboratory the voles were measured, weighed, sexed, their reproduction status and the estimated age according to body-weight (adult, sub-adult or juvenile) were recorded. Furthermore, the animals were dissected, the amount of stomach content was estimated, and five groups were defined: 1 = almost empty, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100%. The next step was to check if the stomach contained root-tissue, which as such is easy to recognize, but in our case, identification at the species-level was not possible. Therefore, only an estimation of the quantity was made. After chemical treatment (see below), root-tissue was removed. If the amount of food items in the stomach was low or the stomachs were almost empty, the collected pellets were used instead (14 cases in all).

### Preparation of the epidermis

A micro-histological approach based on the technique developed by Zettel (1974) was used to assess the dietary composition of the voles. This method assumes that fragments of epidermis and cuticula of plants ingested by animals remain intact as they pass through the digestive system and can be identified in the dung or in the stomach (Stewart, 1966). The time intervals of the chemical treatment were shortened and the whole method was adapted to delicate grasses and forbs.

In order to identify the ingested plant species, epidermis fragments were prepared from the stomach content or faeces. For each trapped vole, one to four slides were prepared, depending on the amount of stomach content or pellets. A total of about 650 microscopic slides were made.

First of all, the stomach content/faecal pellets were softened with distilled water in a glass tube to be able to tease apart the fragments with tweezers. After removing the water, ca. 3 ml of 10% caustic potash solution (KOH) was mixed with the disintegrated droppings and heated in boiling water for about 5-7 minutes. Distilled water was then added to clean the samples. After removing the water, ca. 3 ml of a 1:1 mixture of 10% nitric acid ($HNO_3$) and 10% chromate acid ($H_3CrO_3$) was added. To bleach the epidermis, the glass tube was put into boiling water for ca. 20 seconds until the solution became brownish and bubbles appeared on the epidermis. Thereafter, the acid was immediately removed and distilled water added for cleaning. Parts of the mesophyll were loosened from the epidermis by strong pipetting. Then the plant fragments were allowed to settle for at least five minutes. The water was removed again and 3 ml of an alcoholic solution of Sudan III (96%), a lipophilic dye used for dyeing the cuticle was added. The colouration lasted at least one hour. Finally, the solution was washed with distilled water. The epidermis and the mesophyll were separated through sedimen -

tation. The epidermis-fragments were transferred with a pipette onto a microscopic slide (24 x 60 mm) and then embedded in glycerol gelatine, which was heated. A cover slip (24 x 32 mm) was placed on the slide and sealed with wax to get permanent preparations.

Reference slides from the available plant species in the study sites were made using the same procedure as described above. The time intervals had to be adjusted for the different types of epidermis. At the end of the "acid-treatment" the delicate epidermis was pulled off. Even better preparations were obtained from faecal pellets of test voles fed in the laboratory with known plant species. The droppings were collected after 24 hours and prepared as described above.

### Slide analysis

The microscopic slides were analysed under the microscope at 100x and 400x magnifications. The fragments were identified at the species or plant group level based on the shape and distribution of epidermal cells, the trichomes, the stomata with their guard and subsidiary cells and the structure of the epidermal cells. The lipophilic colouring of the fragments with Sudan III (Zettel, 1974) was helpful as well. Information on these species-specific traits was obtained from a reference collection of epidermis cells of the plants growing in the study sites made at the beginning of the study and some photographs (Rinke, 1987; Zettel, 1974). All identifiable fragments of one plant species were counted by screening the whole slide at low magnification (100x). Since epidermal fragments vary in size, the different sizes of the fragments were taken into account. If there were too many fragments on the slide, so that counting each of them was impossible, the relative abundance on the slide was estimated. From the number of fragment units it was possible to estimate the relative abundance of each plant species in the stomach or in the faeces with an accuracy of 5%.

### Statistical analysis

Non-parametric Mann-Whitney-U-test was used to analyse all the differences between the consumed amount of monocots and dicots within the SWFF and the quasi-natural habitats, respectively. The same test was used to compare the differences of the consumed amount of monocots between the two habitat types. The numbers compared were the percentages for each vole.

To examine if a preference for a given plant species exists, the rank preference index of Johnson (1980) was calculated. The usage of a food resource (quantity of that food resource eaten by an animal) and its availability (presence and accessibility to an animal) were ranked. Then the difference in these two rankings was used as a measure of relative preference.

Johnson (1980) pointed out that the result of this method will be a ranking of relative preferences and that conclusions on absolute preferences should be avoided. As for both usage and availability *ranks* are employed, usage and availability need not be estimated exactly. The sampling procedures (cover estimation) used in this study to determine availability values for the various plants cannot faithfully reflect the true availabilities for the animal and so indications accurate to 1 percent were not possible or reasonable. The same applies to the calculation of the quantity of food items (usage), therefore steps of 5% were used. The rank preference index gives less subjective

results, in the sense that they are less affected by erroneous decisions or observations made by the investigator. It is for these reasons that Manly's alpha (Manly *et al.*, 1972), another measure of preference, very sensitive to data fluctuations or outliers, was not applied.

To calculate the rank preference index (RPI), the following procedure was carried out for each animal (Krebs, 1999):

The rank of usage (r) of the food resource from *1* (most used) to *m* (least used; *m* is also the number of food types) was determined.

The rank of availability of *m* food types in the environment for each species was calculated. To simplify matters it was assumed that these availability ranks were perceived as being the same for all individuals, i.e. each vole was able to reach and eat every plant growing on the site.

The rank difference between usage and availability for each species was calculated. The rank differences across all individuals were averaged (Tbar). The calculated Tbar-values were ranked to give an overall relative preference for all food types.

Note that the calculation of the rank preference index based on frequency of occurrence is problematic, because the Tbar-values (difference between the rank of usage/frequency and the rank of availability, measure of preference) cannot be averaged across individuals since the frequency of occurrence of a plant in the sampled stomachs will only result in one value (see material and methods). Therefore, the RPI according to frequency of occurrence must be calculated without averaging the differences.

For a difference between two ranks (Tbar) to be significant, it must exceed in absolute value W.S, where W is obtained from tables or in our case by the program PREFER provided by Johnson (1980). S stands for the standard error of the difference between two Tbar-values. To determine W one has to select a value for K, the Type I to Type II error-seriousness-ratio. In the present study K=100 was used, which can be regarded as the analogue of the usual Type I significance level of p=0.05 (Johnson, 1980).

Plants connected by a same line (see Tab. 4-9) are not significantly different with regard to preference by the voles; absence of a line means that the food items differ significantly ($p \leq 0.05$). There are no lines in the RPI of frequency of occurrence because the significance of a difference cannot be computed without the standard error of the difference between two means.

Preference will be detected when the usage of a plant is higher than its availability (this is more likely when a plant is relatively rare). If the usage of a plant is less than its availability, no clear preference will appear. Hence, even if the common vole consumes large quantities of a frequent plant A (while usage is *lower* than availability), no preference will be detected. But if it consumes small quantities of a rare plant B (while usage being *higher* than availability), a preference will be detected for plant B although the amount ingested of plant A is much higher than that of plant B.

## RESULTS

### Vegetation cover in SWFF

A total of 51 different plant species was recorded in the three sown wild flower fields: 42 dicots and 9 monocots. The most abundant species over all sites were *Achillea millefolium, Leucanthemum vulgare* and *Trifolium pratense*, all dicots (Tab. 1).

In Grauholz 31 plant species were identified. *A. millefolium* was the most abundant species (25%), followed by *L. vulgare* (24%) and the monocot *Poa pratensis* (12%) (Tab. 1).

In Niederwangen 25 species were identified. *T. pratense* was the most abundant species (32.5%), followed by *L. vulgare* (20%) and *Poa annua/trivialis* (18%) (both species occurred but were not distinguishable at the microscopic level, so were treated as one species) (Tab. 1).

In Uettligen 23 species were identified. *A. millefolium* was the most abundant species (20%), followed by *P. annua/trivialis* (18%) and *Origanum vulgare* (18%) (Tab.1).

### Vegetation cover in quasi-natural habitats

A total of 33 different plant species was recorded in the quasi-natural habitats: 23 dicots and 10 monocots. The most abundant species over all sites were three monocots, *Bromus erectus, Agropyron repens* and *Arrhenatherum elatius* (Tab. 1).

In Riedbach 22 species were identified. *B. erectus* was the most abundant species (52%), followed by *A. elatius* (20%) and the dicot *Galium mollugo* (14%) (Tab. 1).

In Hinterkappelen 16 species were identified. *A. repens* was the most abundant species (52%), followed by *A. elatius* (15%) and *P. annua/trivialis* (15%) (Tab. 1).

In Moosseedorf 22 species were identified. *B. erectus* was the most abundant species (32%), followed by *Deschampsia caespitosa* (30%) and *G. mollugo* (15%) (Tab.1).

### Qualitative and quantitative analysis of detected plants

An ingested plant is assessed here in a qualitative and in a quantitative way. Qualitative means in how many stomachs a given plant species was found (indicated in %). Quantitative means the amount of a plant found in a single stomach (% of the total stomach content). In general, an animal does not feed equally on plants. Usually the plant species occur in different quantities and different frequencies in the stomachs.

#### *Qualitative and quantitative analysis in SWFF*

All in all, the epidermis of 22 different plant species were identified in the stomachs/faeces of voles trapped in sown wild flower fields (14 dicots or 32.6% of the recorded dicots; 8 monocots or 88.9% of the recorded monocots) (Tab. 2). Normally, each vole ingested several plant species, ranging from 1 to 6, with a mode at 3 species.

No animal parts were found except one flea, probably ingested during grooming activities.

In Grauholz (34 voles examined) 10 different species were detected (Tab. 2). Monocots were ingested in larger quantities than dicots (average quantity of 43.1% vs

TAB. 1: Plant species and corresponding cover for SWFF (Sown Wild Flower Fields) and quasi-natural habitats. Species found in stomachs or faeces of voles are in bold face. GH: Grauholz; NW: Niederwangen; UE: Uettligen; RB: Riedbach; HK: Hinterkappelen; MD: Moosseedorf

| Order | Family | SWFF | GH % | NW % | UE % | quasi-natural habitats | RB % | HK % | MD % |
|---|---|---|---|---|---|---|---|---|---|
| **Dicots** | Apiaceae | ***Daucus carota*** | | **5** | | ***Daucus carota*** | **5** | 0.5 | |
| | | *Pastinaca sativa* | | 2 | | | | | |
| | Asteraceae | ***Achillea millefolium*** | **25** | **2** | **20** | ***Achillea millefolium*** | **0.5** | 4 | 0.5 |
| | | ***Anthemis tinctoria*** | 0.5 | **0.1** | 4 | *Erigeron annuus* | 0.5 | | |
| | | *Centaurea cyanus* | 5 | | | *Leontodon autumnalis* | 0.5 | | 0.1 |
| | | ***Centaurea jacea*** | **3** | | **15** | *Solidago canadensis* | 0.5 | | 0.5 |
| | | *Cichorium intybus* | | **2** | | ***Tanacetum vulgare*** | | **5** | |
| | | *Cirsium arvense* | 0.1 | 0.1 | | | | | |
| | | *Cirsium vulgare* | | | 0.5 | | | | |
| | | *Erigeron annuus* | | | 3 | | | | |
| | | *Hieracium caespitosum* | | 0.1 | | | | | |
| | | ***Leucanthemum vulgare*** | **24** | 20 | 3 | | | | |
| | | ***Tanacetum vulgare*** | 12 | | **2** | | | | |
| | | *Taraxacum officinale* | 0.5 | | | | | | |
| | Boraginaceae | *Echium vulgare* | | | 0.5 | | | | |
| | | *Myosotis arvensis* | 2 | | | | | | |
| | Brassicaceae | *Cardamine pratensis* | 0.5 | 2 | | *Cardamine pratensis* | 0.5 | | |
| | Caryophyllaceae | *Agrostemma githago* | | 0.5 | | ***Silene vulgaris*** | **0.5** | | 0.5 |
| | | *Silene alba* | 0.5 | 0.5 | | | | | |
| | | *Stellaria media* | | 0.1 | | | | | |
| | Dipsacaceae | *Dipsacus fullonum* | 2 | | 5 | ***Knautia arvensis*** | **0.5** | | |
| | Fabaceae | ***Medicago sativa*** | 12 | **15** | | ***Medicago lupulina*** | **0.5** | | |
| | | *Onobrychis viciifolia* | 0.5 | | | ***Vicia cracca*** | **4** | | 5 |
| | | ***Trifolium pratense*** | | 32.5 | **16** | | | | |
| | | ***Trifolium repens*** | **0.5** | | | | | | |
| | Geraniaceae | ***Geranium dissectum*** | 0.5 | **2** | | ***Geranium pyrenaicum*** | **0.5** | | 0.5 |
| | Hypericaceae | *Hypericum perforatum* | 12 | | 0.5 | *Hypericum perforatum* | | 0.5 | |
| | Lamiaceae | *Lamium purpureum* | 0.5 | 0.1 | | *Lamium purpureum* | 0.5 | 0.5 | 0.5 |
| | | *Origanum vulgare* | 3 | | 18 | *Origanum vulgare* | | 5 | 0.5 |
| | | *Thymus pulegioides* | 0.5 | | | *Salvia pratensis* | 0.5 | | 0.5 |
| | | | | | | *Thymus pulegioides* | 0.5 | | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Malvaceae | *Malva moschata* | *0.5* | | | *Malva moschata* | | | *0.5* |
| | Onagraceae | *Epilobium angustifolium* | *0.5* | | *0.5* | | | | |
| | Papaveraceae | *Papaver rhoeas* | | *0.5* | | *Papaver rhoeas* | | | *0.5* |
| | Plantaginaceae | ***Plantago lanceolata*** | ***0.5*** | ***3*** | | *Plantago lanceolata* | | *1* | |
| | | ***Plantago major*** | | ***3*** | | | | | |
| | Ranunculaceae | | | | | *Ranunculus acer* | | *4* | |
| | Rosaceae | *Fragaria vesca* | | | *4* | *Fragaria vesca* | *0.5* | | *0.5* |
| | Rubiaceae | *Galium aparine* | | | *4* | ***Galium mollugo*** | ***14*** | ***5*** | ***15*** |
| | | ***Galium mollugo*** | | | ***3*** | | | | |
| | Scrophulariaceae | *Verbascum densiflorum* | *0.5* | *3* | | | | | |
| | | *Verbascum thapsiforme* | *0.5* | | *0.5* | | | | |
| | Urticaceae | *Urtica dioica* | *0.5* | | | | | | |
| | Veronicaceae | ***Veronica persica*** | ***0.5*** | | | | | | |
| **Monocots** | Poaceae | ***Agropyron repens*** | | ***4*** | ***3*** | ***Agropyron repens*** | | ***52*** | |
| | | ***Alopecurus geniculatus*** | ***0.5*** | | | ***Alopecurus geniculatus*** | ***3*** | | ***3*** |
| | | ***Arrhenatherum elatius*** | ***0.5*** | ***5*** | ***3*** | ***Anthoxanthum odoratum*** | ***3*** | *4* | *0.5* |
| | | ***Dactylis glomerata*** | | | ***4*** | ***Arrhenatherum elatius*** | ***20*** | ***15*** | ***5*** |
| | | ***Holcus lanatus*** | | ***0.1*** | | ***Bromus erectus*** | ***52*** | | ***32*** |
| | | ***Lolium perenne*** | | ***5*** | *0.5* | ***Dactylis glomerata*** | ***4*** | ***0.5*** | *6* |
| | | *Phleum pratense* | | | *0.5* | *Deschampsia caespitosa* | | *0.5* | *30* |
| | | ***Poa annua/trivialis*** | ***5*** | ***18*** | ***18*** | ***Holcus lanatus*** | ***0.5*** | ***2*** | *4* |
| | | ***Poa pratensis*** | ***12*** | | | ***Poa annua/trivialis*** | | ***15*** | ***5*** |
| | | | | | | ***Poa pratensis*** | | ***5*** | |

TAB. 2: Ingested plant species from SWFF, listed alphabetically; comparison of vegetation cover in the field, average quantity (% of the total stomach content) and frequency of occurrence (% of the total number of stomachs). The values of the three highest ranking plant species of each site are in bold italics. Number of examined voles is 99. Abbreviations as in Table 1.

| | Cover (%) | | | Quantity ingested (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant species | GH | NW | UE | GH | NW | UE | aver. | GH | NW | UE | average |
| **Dicots** | | | | | | | | | | | |
| *Achillea millefolium* | 25.0 | 2.0 | 20.0 | ***9.0*** | 1.1 | 1.5 | **3.87** | ***42.4*** | 10.0 | 20.0 | **24.13** |
| *Anthemis tinctoria* | 0.5 | 0.1 | 4.0 | - | 0.1 | - | **0.03** | - | 2.5 | - | **0.83** |
| *Centaurea jacea* | 3.0 | - | 15.0 | 1.8 | - | 2.8 | **1.53** | 9.1 | - | 15.0 | **8.03** |
| *Cichorium intybus* | - | 2.0 | - | - | 1.5 | - | **0.50** | - | 10.0 | - | **3.33** |
| *Daucus carota* | - | 5.0 | - | - | 4.0 | - | **1.33** | - | 25.0 | - | **8.33** |
| *Galium verum* | - | | 3.0 | - | - | 1.8 | **0.60** | - | - | 10.0 | **3.33** |
| *Geranium dissectum* | 0.5 | 2.0 | - | - | 0.1 | - | **0.03** | - | 2.5 | - | **0.83** |
| *Leucanthemum vulgare* | 24.0 | 20.0 | 3.0 | 0.5 | - | - | **0.16** | 6.1 | - | - | **2.03** |
| *Medicago sativa* | 12.0 | 15.0 | - | - | 1.0 | - | **0.33** | - | 7.5 | - | **2.50** |
| *Plantago sp.* | 0.5 | 3.0 | - | 3.9 | ***12.5*** | - | **5.47** | 21.2 | ***37.5*** | | **19.57** |
| *Tanacetum vulgare* | 12.0 | - | 2.0 | - | - | 0.8 | **0.27** | - | - | 15.0 | **5.00** |
| *Trifolium pratense* | 0.5 | 32.5 | 16.0 | - | ***12.9*** | 2.5 | **5.13** | - | ***37.5*** | 15.0 | **17.50** |
| *Trifolium repens* | 0.5 | - | 16.0 | 0.9 | - | - | **0.30** | 6.1 | - | - | **2.02** |
| *Veronica persica* | 0.5 | - | - | 0.2 | - | - | **0.07** | 3.1 | - | - | **1.03** |
| **Monocots** | | | | | | | | | | | |
| *Agropyron repens* | - | 4.0 | 3.0 | - | 9.6 | ***27.2*** | **12.27** | - | ***50.0*** | ***65.0*** | **38.33** |
| *Alopecurus geniculatus* | 0.5 | - | - | 0.9 | - | - | **0.30** | 6.1 | - | - | **2.03** |
| *Arrhenatherum elatius* | 0.5 | 5.0 | 3.0 | 2.7 | 5.3 | ***8.7*** | **5.57** | 12.1 | 27.5 | ***30.0*** | **23.20** |
| *Dactylis glomerata* | - | - | 4.0 | - | - | 0.4 | **0.13** | - | - | 5.0 | **1.67** |
| *Holcus lanatus* | | 0.1 | - | - | 0.5 | - | **0.17** | - | 2.5 | - | **0.83** |
| *Lolium perenne* | - | 5.0 | 0.5 | - | 0.5 | - | **0.17** | - | 5.0 | - | **1.67** |
| *Poa annua/trivialis* | 5.0 | 18.0 | 18.0 | ***15.6*** | ***20.6*** | ***17.0*** | **17.73** | ***63.6*** | ***65.0*** | ***45.0*** | **57.87** |
| *Poa pratensis* | 12.0 | - | - | ***23.9*** | - | - | 7.97 | ***78.8*** | - | - | **26.27** |
| **Seeds** | | | | 14.8 | 16.5 | 27.0 | **19.43** | 76.0 | 83.0 | 90.0 | **83.00** |

16.3%) and more often (frequency of occurrence of 78.8% vs 42.4%). Seeds were found at an average quantity of 14.8% and a frequency of occurrence of 76.0%. The remaining 25.8% stomach content were roots and unidentified material.

*Poa pratensis* was the main food plant (average quantity of 23.9% and frequency of 78.8% for all sampled stomachs). *Poa annua/trivialis* represented 15.6% of the diet and occurred in 63.6% of all stomachs. An important food plant was also *Achillea millefolium* (9% of the diet and in 42.4% of all sampled stomachs).

In Niederwangen (42 voles examined) 13 plant species were found in the stomachs (Tab. 2). Monocots were ingested in larger quantities than dicots (average quantity of 36.5% vs 33.2%) and more often (frequency of occurrence of 65.0% vs 37.5%). Seeds were found at an average quantity of 16.5% and with a frequency of 83.0%. The remaining 13.8% of stomach content were roots and unidentified material.

*Poa annua/trivialis* was the main food plant (average quantity of 20.6%) and reached the highest frequency of occurrence (65.0%). *Trifolium pratense* was ingested at an average quantity of 12.9% and reached a frequency of 37.5%. The average quantity of *Agropyron repens* in the diet was 9.6%. It appeared with a frequency of 50.0% in all sampled stomachs.

In Uettligen (23 voles examined) 9 different plant species were found in the diet (Tab. 2). The average quantity of consumed monocots was 53.3% and their frequency of occurrence 65.0% of the sampled stomachs. The average quantity of consumed dicots was 9.4% only. Dicots were found in 20.0% of the sampled stomachs and seeds at an average quantity of 27.0% and with a frequency of 90.0%. The remaining 10.3% of stomach content were roots and unidentified material.

*Agropyron repens* was an important food plant as well (average quantity of 27.2% and found in 65.0% of all sampled stomachs). *Poa annua/trivialis* was consumed at an average quantity of 17.0% and a frequency of occurrence of 45.0% and *Arrhenatherum elatius* amounted to an average quantity of 8.7% with a frequency of occurrence of 30.0% of all sampled stomachs.

*Differences between monocots and dicots*

For this comparison, we took into account the percentages (0 – 100%) of occurrences of each plant species ingested, separately for each site. The values of all three sites were then combined. The total number of observations is greater than the number of captured voles, as several species of plants can be found in a given vole. A Mann-Whitney-U-test showed a significant difference in favour of monocots ($p < 0.0001$, $n_{monocots}=380$, $n_{dicots}=562$).

*Qualitative and quantitative analysis in quasi-natural habitats*

Overall, the epidermis of 18 different plant species were identified in the stomachs / faeces of voles trapped in quasi-natural habitats (9 dicots, 37.5%% of the growing dicots; 9 monocots, 90% of the growing monocots) (Tab. 3). Each vole ingested several plant species, ranging from 1 to 5, with a mode at 3. No animal parts were found.

In Riedbach (53 voles examined) 14 different species were found. Monocots were ingested in larger quantities than dicots (65.0% vs 17.1%) and a frequency of occurrence of 88.7% vs 32.1%. Seeds amounted to 6.6%, with a frequency of 14.0%. The remaining 11.3% of stomach content were roots and unidentified material.

*Arrhenatherum elatius* was the most important food plant. The stomachs contained 25.9% of this monocot, while 88.7% of all stomachs had fragments of this grass species. The average quantity of *Bromus erectus* was 37.1% and was found in 83.0% of all sampled stomachs. *Galium mollugo* amounted to 7.0%, with a frequency of 26.4%.

In Hinterkappelen (30 voles examined) 8 species were found. Monocots were ingested in larger quantities than dicots (81.9% vs 6.2%) and found in 100% vs 40.7% of the sampled stomachs. Seeds amounted to 8.4%, with a frequency of 67.0%. The remaining 3.5% of stomach content were roots and unidentified material.

The average quantity of *Arrhenatherum elatius* was 54.5% and the grass appeared in 100% of all examined stomachs. *Agropyron repens* reached 10.4% and a frequency of 59.3%, whereas *Poa pratensis* amounted to 6.9%, with a frequency of 48.1%.

In Moosseedorf (15 voles examined) the diet comprised only 5 species. Monocots were ingested in larger quantities than dicots (66.0% vs 9.6%) and appeared in 63.6% vs 36.4% of the stomachs. In this site, the only dicot found in the stomach

TAB. 3: Ingested plant species from quasi-natural habitats, listed alphabetically; comparison of vegetation cover in the field, average quantity (% of the total stomach content) and frequency of occurrence (% of the total number of stomachs). The values of the three highest ranking plant species of each site are in bold italics. Number of examined voles is 99. Abbreviations as in Table 1.

| | Cover (%) | | | Quantity ingested (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant species | RB | HK | MD | RB | HK | MD | aver. | RB | HK | MD | aver. |
| **Dicots** | | | | | | | | | | | |
| *Achillea millefolium* | 0.5 | 4.0 | 0.5 | 1.3 | - | - | **0.43** | 7.6 | - | - | **2.53** |
| *Daucus carota* | 4.0 | 0.5 | - | 1.2 | - | - | **0.40** | 11.3 | - | - | **3.77** |
| *Galium mollugo* | 14.0 | 3.0 | 15.0 | ***7.0*** | 6.0 | ***9.6*** | **7.53** | 26.4 | 40.7 | ***36.4*** | **34.50** |
| *Geranium pyrenaicum* | 0.5 | - | 0.5 | 0.2 | - | - | **0.07** | 1.9 | - | - | **0.63** |
| *Knautia arvensis* | 0.5 | - | - | 0.2 | - | - | **0.07** | 1.9 | - | - | **0.63** |
| *Medicago lupulina* | 0.5 | - | - | 0.2 | - | - | **0.07** | 1.9 | - | - | **0.63** |
| *Silene vulgaris* | 0.5 | - | 0.5 | 1.0 | - | - | **0.33** | 1.9 | - | - | **0.63** |
| *Tanacetum vulgare* | 0.5 | 2.0 | - | - | 0.2 | - | **0.07** | - | 3.7 | - | **1.23** |
| *Vicia cracca* | 4.0 | - | - | 6.0 | - | - | **2.00** | ***32.1*** | - | - | **10.70** |
| **Monocots** | | | | | | | | | | | |
| *Agropyron repens* | - | 52.0 | - | - | ***10.4*** | - | **3.46** | - | ***59.3*** | - | **19.77** |
| *Alopecurus pratense* | 3.0 | - | 3.0 | 0.3 | - | 6.4 | **2.23** | 1.9 | - | 18.2 | **6.70** |
| *Anthoxantum odoratum* | 3.0 | 3.0 | 0.5 | 0.04 | - | - | **0.01** | 1.9 | - | - | **0.63** |
| *Arrhenatherum elatius* | 20.0 | 15.0 | 5.0 | ***25.9*** | ***54.5*** | ***27.7*** | **36.03** | ***88.7*** | ***100.0*** | ***63.6*** | **84.10** |
| *Bromus erectus* | 52.0 | - | 32.0 | ***37.1*** | - | ***22.3*** | **19.80** | ***83.0*** | - | ***63.6*** | **48.89** |
| *Dactylis glomerata* | 4.0 | 0.5 | - | 1.2 | 1.3 | - | **0.83** | 13.2 | 11.1 | - | **8.10** |
| *Holcus lanatus* | 0.5 | 2.0 | 3.0 | 0.5 | 1.0 | - | **0.50** | 5.7 | 11.1 | - | **5.60** |
| *Poa annua/trivialis* | - | 15 | 4.0 | - | ***7.8*** | ***9.6*** | **5.80** | - | 29.6 | 18.2 | **15.93** |
| *Poa pratensis* | - | 5.0 | - | - | 6.9 | - | **2.30** | - | ***48.1*** | - | **16.03** |
| **Seeds** | | | | 6.6 | 8.4 | 17.0 | **10.67** | 14.0 | 67.0 | 100.0 | **60.33** |

was *Galium mollugo*. Seeds represented 17%, with a frequency of 100%. The remaining 7.4% of stomach content were roots and unidentified material.

*Arrhenatherum elatius* appeared at an average quantity of 27.7% and at a frequency of 63.6% of all sampled stomachs. *Bromus erectus* amounted to 22.3% and appeared in 63.6% of all sampled stomachs. The corresponding values for *G. mollugo* are 9.6% and 36.4%, and for *Poa annua/trivialis* 9.6% and 18.2%.

*Differences between monocots and dicots*

Using the same calculations as above, the Mann-Whitney-U-test showed a significant difference ($p < 0.0001$, $n_{monocots}=489$, $n_{dicots}=496$) between monocots and dicots, again in favour of monocots.

## COMPARISON BETWEEN HABITATS BASED ON MONOCOTS, SEEDS AND ROOTS INGESTED

We took into account the percentages (0 - 100%) of occurrences of each monocot species ingested, separately for each site. The values of all three sites from SWFF, respectively quasi-natural habitat, were then combined. Again the total number of observations is greater than the number of captured voles, for the reasons mentioned above. A Mann-Whitney-U-test showed no significant difference ($p = 0.270$, $n_{swff} = 380$, $n_{quasi} = 496$) between the habitats.

The quantity of seeds ingested showed a significant difference (Mann-Whitney-U-test, $p < 0.001$, $n_{swff} = 99$, $n_{quasi} = 98$, zero-percentage-values were included), whereby seeds were ingested in larger quantities in the SWFF than in the quasi-natural habitats.

There was more root-tissue in the stomachs of voles from SWFF than from quasi-natural habitats, but the difference was not significant (Mann-Whitney-U-test, $p = 0.214$ $n_{swff} = 99$, $n_{quasi} = 98$, zero-percentage-values were included).

### Food Preference in SWFF

In each site (Tab. 4-6), the null hypothesis "all components are equally preferred" was always rejected, i.e. preferences for different plants exist. However, no clear preference pattern was found. Although *Poa annua/trivialis* was the most ingested species (Tab. 2), *M. arvalis* had no clear preference for that plant. *Agropyron repens* was the second most ingested species, which was highly preferred in Uettligen, but only selected at an average level in Niederwangen. Overall, neither the monocots nor the dicots were primarily selected, although the amount of ingested monocots was higher than the dicots. The preferences for quantity and for frequency of occurrence showed a similar pattern, since both factors were positively correlated.

### Food preferences in quasi-natural habitats

As shown in Tab. 7-9 there is a preference for some plants, although no clear preference pattern appears. *Arrhenatherum elatius* was the most ingested species, but *M. arvalis* had no clear preference for it. Also *Bromus erectus*, the second most ingested plant species, was not clearly preferred. In Hinterkappelen, *Galium mollugo* was highly preferred, whereas in Riedbach it was the least preferred food item. Again, the preference for quantity and for frequency of occurrence showed a similar pattern, due to their positive correlation.

## DISCUSSION

### Diet composition

The diet of *M. arvalis* in SWFF and in quasi-natural habitats included various dicots and almost every monocot growing locally. Other studies showed as well that the common vole has a species-rich food spectrum. With one exception, we did no find animal components in its diet contrary to Holisova (1975) who noted that they ingested considerable amounts of animal fragments.

Although more plant species were growing in SWFF than in quasi-natural habitats, the common vole did not consume higher amounts, or more often, the additional sown wild flowers. On the contrary, the present study shows that the vole fed most often on grasses even in the SWFF where grasses were less abundant than sown wild flowers. It seems that the additional sown wild flowers are not attractive to the common vole as food plants. Briner *et al.* (2005) mention that the abundance of food resources in SWFF is a key factor that accounts for the small home range sizes in these habitats, suggesting that the distribution of food is the major factor influencing the spacing system of voles and hence its higher density in SWFF. This seems to be

TAB. 4: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Grauholz. All plants were not equally preferred: $F (9, 25) = 227.9$, $p<0.001$, $W=1.85$ Plants connected by a same line are not significantly different in preference by the voles; no line means that the food items differ significantly ($p \leq 0.05$). There are no lines in the frequency of occurrence because the significance of a difference cannot be computed without the standard error of the difference between two means.

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Plantago lanceolata* | -2.411 | 1 | *Plantago lanceolata* |
| 2 | *Arrhenatherum elatius* | -1.779 | 2 | *Arrhenatherum elatius* |
| 3 | *Alopecurus pratensis* | -1.500 | 3 | *Poa pratensis* |
| 4 | *Trifolium pratense* | -1.485 | 4 | *Poa trivialis* |
| 5 | *Veronica persica* | -1.368 | 5 | *Alopecurus pratensis* |
| 6 | *Poa trivialis* | -0.559 | 6 | *Trifolium pratensis* |
| 7 | *Poa pratensis* | -0.324 | 7 | *Veronica persica* |
| 8 | *Centaurea jacea* | 1.309 | 8 | *Centaurea jacea* |
| 9 | *Achillea millefolium* | 3.559 | 9 | *Achillea millefolium* |
| 10 | *Leucanthemum vulgare* | 4.559 | 10 | *Leucanthemum vulgare* |

TAB. 5: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Niederwangen. All plants were not equally preferred: $F (12, 30) = 183.47$, $p<0.001$, $W=1.82$

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Holcus lanatus* | -4.238 | 1 | *Agropyron repens* |
| 2 | *Anthemis tinctoria* | -4.200 | 2 | *Plantago sp.* |
| 3 | *Cichorium intybus* | -2.163 | 3 | *Achillea millefolium* |
| 4 | *Achillea millefolium* | -2.100 | 4 | *Cichorium intybus* |
| 5 | *Plantago sp.* | -2.063 | 5 | *Poa trivialis* |
| 6 | *Agropyron repens* | -1.813 | 6 | *Arrhenatherum elatius* |
| 7 | *Geranium pyrenaicum* | -1.688 | 7 | *Anthemis tinctoria* |
| 8 | *Arrhenatherum elatius* | 1.750 | 8 | *Holcus lanatus* |
| 9 | *Poa trivialis* | 1.925 | 9 | *Daucus carota* |
| 10 | *Daucus carota* | 1.938 | 10 | *Geranium pyrenaicum* |
| 11 | *Lolium perenne* | 2.988 | 11 | *Trifolium pratense* |
| 12 | *Trifolium pratense* | 4.713 | 12 | *Lolium perenne* |
| 13 | *Medicago sativa* | 4.950 | 13 | *Medicago sativa* |

TAB. 6: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Uettligen. All plants were not equally preferred: $F (8, 15) = 42.51$, $p<0.001$, $W=1.90$

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Agropyron repens* | -3.225 | 1 | *Agropyron repens* |
| 2 | *Galium mollugo* | -2.650 | 2 | *Arrhenatherum elatius* |
| 3 | *Tanacetum vulgare* | -1.900 | 3 | *Tanacetum vulgare* |
| 4 | *Arrhenatherum elatius* | -1.575 | 4 | *Poa trivialis* |
| 5 | *Centaurea jacea* | 0.650 | 5 | *Gallium mollugo* |
| 6 | *Trifolium pratense* | 1.750 | 6 | *Centaurea jacea* |
| 7 | *Dactylis glomerata* | 1.900 | 7 | *Achillea millefolium* |
| 8 | *Poa trivialis* | 2.150 | 8 | *Trifolium pratense* |
| 9 | *Achillea millefolium* | 2.900 | 9 | *Dactylis glomerata* |

TAB. 7: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Riedbach. All plants were not equally preferred: F (13, 40) = 146.95, p<0.001, W=1.79

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Vicia cracca* | -4.566 | 1 | *Holcus lanatus* |
| 2 | *Achillea millefolium* | -3.066 | 2 | *Vicia cracca* |
| 3 | *Holcus lanatus* | -2.755 | 3 | *Alopecurus pratensis* |
| 4 | *Silene vulgaris* | -2.707 | 4 | *Arrhenatherum elatius* |
| 5 | *Medicago lupulina* | -2.698 | 5 | *Achillea millefolium* |
| 6 | *Knautia arvensis* | -2.689 | 6 | *Dactylis glomerata* |
| 7 | *Arrhenatherum elatius* | 0.622 | 7 | *Geranium pyrenaicum* |
| 8 | *Authoxanthum odoratum* | 1.141 | 8 | *Bromus erectus* |
| 9 | *Alopecurus pratensis* | 1.292 | 9 | *Galium mollugo* |
| 10 | *Bromus erectus* | 1.575 | 10 | *Daucus carota* |
| 11 | *Dactylis glomerata* | 3.047 | 11 | *Knautia arvensis* |
| 12 | *Daucus carota* | 3.141 | 12 | *Medicago lupulina* |
| 13 | *Geranium pyrenaicum* | 3.594 | 13 | *Authoxanthum odoratum* |
| 14 | *Galium mollugo* | 4.066 | 14 | *Silene vulgaris* |

TAB. 8: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Hinterkappelen. All plants were not equally preferred: F (7, 23) = 95.57, p<0.001, W=1.89

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Dactylis glomerata* | -2.315 | 1 | *Galium mollugo* |
| 2 | *Holcus lanatus* | -1.333 | 2 | *Arrhenatherum elatius* |
| 3 | *Galium mollugo* | -1.278 | 3 | *Dactylis glomerata* |
| 4 | *Arrhenatherum elatius* | -1.259 | 4 | *Poa pratensis* |
| 5 | *Poaa pratensis* | -0.278 | 5 | *Holcus lanatus* |
| 6 | *Tanacetum vulgare* | 1.407 | 6 | *Agropyron repens* |
| 7 | *Poa trivialis* | 2.259 | 7 | *Poa trivialis* |
| 8 | *Agropyron repens* | 2.786 | 8 | *Tanacetum vulgare* |

TAB. 9: Rank preference index according to Johnson for quantity and frequency of occurrence in the field Moosseedorf. All plants were not equally preferred: F ( 4, 11) = 34.90, p< 0.001, W=2.21

| Rank | Quantity | Tbar | Rank | Frequency of occurrence |
|---|---|---|---|---|
| 1 | *Alopecurus pratensis* | -1.773 | 1 | *Galium mollugo* |
| 2 | *Arrhenatherum elatius* | -0.727 | 2 | *Bromus erectus* |
| 3 | *Poa trivialis* | -0.500 | 3 | *Poa trivialis* |
| 4 | *Galium mollugo* | 1.227 | 4 | *Alopecurus pratensis* |
| 5 | *Bromus erectus* | 1.772 | 5 | *Arrhenatherum elatius* |

verified in our study plots, as plants growing there naturally, mainly grasses, are a major food supply, while flowers are not. It is possible that the root- and seed-supply in SWFF is another key factor, which attracts the voles, as seeds were significantly more often ingested in SWFF than in quasi-natural habitats. The same applies to roots. More root-tissue was found in the stomachs of voles from SWFF than from quasi-natural habitats, although the difference was non significant. Roots were only

consumed in small amounts. This could be related to the unusually mild winter of 2006/07 with temperatures in February 3 to 4 degrees above average. It is possible that the proportion of roots would have been higher during a harsh winter, i.e. when annual plants are less abundant.

It is important to note that a lot of plants recorded by Balmelli *et al.* (1999) and Baumann (1996) showed feeding signs on roots and seeds and not on leaves. With the method used in our study it was not possible to identify roots and seeds at the species level and only the epidermis from green plant parts was considered. Therefore, these studies are not directly comparable with each other, as they are based on different approaches. Nonetheless, it can be assumed that the food-spectrum of *M. arvalis* is even broader than the present work suggests. This assumption agrees with data from other authors, which show longer lists of ingested species (Rinke, 1990; Truszkowski 1982).

### Food preference

No clear food preference pattern was found. Although monocots were the most frequently ingested plants and the amount consumed was high, they were not always the most preferred, when comparing usage to availability. In contrast, dicots were eaten in significant lower proportions than monocots, but nevertheless, they were preferred in some cases. Many studies have shown that voles do select certain plant species (Balmelli *et al.*, 1999; Leutert, 1983; Rinke, 1990; Yu *et al.*, 1980). These studies and the present work show that the food intake of *M. arvalis* depends only to some extent on the availability of the food-components, at least in habitats with a broad spectrum of food-supply.

Our results do not always agree with the observations of other authors. Yu *et al.* (1980) found that *Taraxacum officinale* was the most important food plant in the studied population, followed by *Medicago lupulina*, *Anthoxanthum odoratum* and *Bromus erectus*. In our case, *T. officinale* occurred only in one site, and at small density. Further important food resources in the study of Yu *et al.* (1980) were *Arrhenatherum elatius*, *Holcus lanatus*, *Trifolium repens*, *Lolium perenne* and *Phleum pratense*, which corresponds largely to our results. Rinke (1990) observed that *Poa pratensis*, *Poa trivialis* and *A. elatius* were ingested frequently and in large quantities, a fact consistent with our data. In agreement with Rinke (1989), *Leucanthemum vulgare*, *Achillea millefolium* and *Centaurea jacea* (frequent plants in our study plots) were rarely detected in the voles' stomachs/faeces and only in small quantities.

Balmelli *et al.* (1999) studied food preferences in laboratory feeding tests and analysed the plant nutritional components (nitrogen, sugar, starch and phenolics) as well as energy and water content. They found clear preferences, but were unable to find any relationship between preference and nutritional parameters. Preferences are probably influenced by a complex of different factors. Apart from the nutrient content and chemical substances, physical properties such as leaf thickness, hardness of leaves, trichomes or water content can play a role as well.

### Rank preference index

The calculated rank preference index suggests that there is a preference of *M. arvalis* for sown wild flowers in some sites. A significant preference will only be

detected when the usage of a plant is higher than its availability. *Bromus erectus* in Riedbach grew in large quantities and was ingested frequently and in relatively high amounts, as well. As the usage was lower than the availability, no significant preference for this plant was observed. On the contrary, a plant like *Tanacetum vulgare*, growing in small quantities, resulted in a high preference because its usage was higher than availability.

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## REFERENCES

ASCHWANDEN, J., BIRRER, S. & JENNI, L. 2005. Are ecological compensation areas attractive hunting sites for common kestrels (*Falco tinnunculus*) and long-eared owls (*Asio otus*)? *Journal of Ornithology* 146: 279-286.

BAUMANN, L. 1996. The influence of field margins to populations of small mammals – A study of the population ecology of the common vole *Microtus arvalis* in sown weed strips. *Diploma thesis, Zoologisches Institut der Universität Bern.*

BALMELLI, L., NENTWIG, W. & AIROLDI, J.-P. 1999. Food preferences of the common vole *Microtus arvalis* in the agricultural landscape with regard to nutritional components of plants. *Zeitschrift für Säugetierkunde* 64: 154-168.

BATZLI, G. O. & PITELKA, F. 1983. Nutritional ecology of microtine rodents: food habits of lemmings near Barrow, Alaska. *Journal of Mammalogy* 64: 648-655.

BRAUN-BLANQUET, J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde, 3. Auflage. *Springer Verlag, Berlin, Wien, New York.*

BRINER, T., NENTWIG, W. & AIROLDI, J.-P. 2005. Habitat quality of wild flower strips for common voles (*Microtus arvalis*) and its relevance for agriculture. A*griculture Ecosystems and Environment* 95: 321-325.

EGGENBERG, S. & MÖHL, A. 2007. Flora Vegetativa. *Haupt, Bern.*

EGGENSCHWILER, L. & JACOT, K. 2001. 30 Pflanzen der Brache entdecken! *LBL, Lindau.*

FRANK, T. & NENTWIG, W. 1995. Ground dwelling spiders (Araneae) in sown weed strips and adjacent fields. *Acta Oecologica* 16: 179-193.

HANSSON, L. 1970. Methods of morphological diet microanalysis in rodents. *Oikos* 21: 256-266.

HEITZMANN, A. & NENTWIG, W. 1993. Angesäte Ackerkrautstreifen in der Agrarlandschaft: Eine Möglichkeit zur Vermehrung des Nützlingspotentials und zur Kontrolle von Schädlings-Populationen, somit der Förderung der Biodiversität in der Kulturlandschaft, bei gleichzeitig intensiver landwirtschaftlicher Nutzung. *Schweizerische landwirtschaftliche Forschung* 32: 365-383.

HOLISOVA, V. 1975. The foods eaten by Rodents in reed swamps of Nesyt Fishpond. *Zoologicke Listy* 24: 223-237.

JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61: 65-71. [Jamestown, ND: Northern Prairie Wildlife Research Centre Online. http://www.npwrc.usgs.gov/resource/methods/prefer/index.htm (Version 16 July 1997)].

KREBS, C. J. 1999. Ecological Methodology, 2nd Edition. *Addison-Welsey Educational Publishers, Inc., Menlo Park, California.*

LAUBER, K. & WAGNER, G. 2001. Flora Helvetica. *Haupt, Bern.*

LEICHT, W. H. 1979. Tiere der offenen Kulturlandschaft. *Quelle und Meyer, Heidelberg.*

LEUTERT, A. 1983. Einfluss der Feldmaus, *Microtus arvalis* (Pall.), auf die floristische Zusammensetzung von Wiesenökosystemen. *Veröffentlichungen des geobotanischen Institutes der ETH, Stiftung Rübel, Zürich.*

LILLE, R. 1996. Zur Bedeutung von Brachefläachen für die Avifauna der Agrarlandschaft: Eine nahrungsökologische Studie an der Goldammer *Emberiza citronella. Agrarökologie* 21: 1-150.

MANLY, B. F. J., MILLER, P. & COOK, L. M. 1972. Analysis of a selective predation experiment. *Am. Nat.* 106: 719-736.

NENTWIG, W. 2000. Die Bedeutung von streifenförmigen Strukturen in der Kulturlandschaft (pp. 1-40). *In*: NENTWIG, W. (Hrsg.): Streifenförmige ökologische Ausgleichsflächen in der Kulturlandschaft: Ackerkrautstreifen, Buntbrache, Feldränder. *Verlag Agrarökologie, Bern und Hannover.*

NIETHAMMER, J. & KRAPP, F. 1982. *Microtus arvalis* (Pallas, 1779) – Feldmaus (pp. 284-318). *In*: NIETHAMMER, J. & KRAPP, F. (Hrsg.): Handbuch der Säugetiere Europas, Band 2/I, Rodentia II. *Akademische Verlagsgesellschaft, Wiesbaden.*

PUTMAN, R. J. 1984. Facts from faeces. *Mammal Reviews* 14: 79-97.

RINKE, T. 1987. Untersuchung zur Nahrungsökologie wiesenbewohnender Feldmäuse (*Microtus arvalis* Pallas, 1779). *Dissertation, Justus Liebig-Universität, Giessen.*

RINKE, T. 1990. Zur Nahrungsökologie von *Microtus arvalis* (Pallas, 1779) auf Dauergrünland. I. Allgemeine Nahrungspräferenzen. *Zeitschrift für Säugetierkunde* 55: 106-114.

RINKE, T. 1991. Percentage of volume versus number of species: availability and intake of grasses and forbs in *Microtus arvalis. Folia Zool.* 40: 143-151.

STEIN, G. H. W. 1958. Die Feldmaus *Microtus arvalis* Pallas. *Die neue Brehm-Bücherei. Ziemsen Wittenberg.*

STEWART, D. R. M. 1966. Analysis of plant epidermis in faeces: a technique for studying the food preferences of grazing herbivores. *Journal of applied Ecology* 4: 83-111.

TRUSZKOWSKI, J. 1982. The impact of the common vole on the vegetation of agroecosystems. *Acta Theriologica* 27: 305-345.

YU, O., VERGNE, Y. & GOUNOT, M. 1980. Modèle d'interaction entre campagnols *Microtus arvalis* et prairie permanente. *Revue d'Ecologie (Terre et Vie)* 34: 373-426.

WESTOBY, M., ROST G. R. & WEIS, J. A. 1976. Problems with estimating herbivore diets by microscopically identifying plant fragments from stomachs. *Journal of Mammalogy* 57: 167-172.

ZETTEL, J. 1974. Mikroskopische Epidermiskennzeichen von Pflanzen als Bestimmungshilfen. *Mikrokosmos* 63: 106-111, 136-139, 177-181, 201-206.

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# Phenology of two syntopic *Eukoenenia* species in a northern Italian forest soil (Arachnida: Palpigradi)

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**Phenology of two syntopic *Eukoenenia* species in a northern Italian forest soil (Arachnida: Palpigradi).** - The present paper provides evidence for the co-occurrence of edaphic palpigrade species in Europe. *Eukoenenia mirabilis* and *E. gallii* coexist in the soil of a cork oak plantation on the Ligurian coast in northwestern Italy. Year-round sampling there produced, for the first time in a temperate zone, complete annual cycles of palpigrade populations. In the study area *E. mirabilis* and *E. gallii* are univoltine. Both species reproduce in summer and overwinter predominantly in the adult stage. The balanced sex-ratio of the resident *E. mirabilis* population is remarkable, because males of this widespread species are usually rare or absent.

**Keywords:** Palpigrades - edaphic - life cycle - sex ratio - Romania - Italy.

## INTRODUCTION

The majority of the currently known 84 extant species of Palpigradi (Harvey, 2003; updated) live in soil. Subterranean habitats – usually caves and, occasionally, rock debris (Christian, 2004) – accommodate about 30 species, apart from exceptional cave records of soil dwellers. In Europe, however, the soil/cave ratio is in favor of cavernicolous palpigrades. Among the 26 indigenous species, all of which belong to the genus *Eukoenenia*, only a few are considered as edaphic: *E. mirabilis* (Grassi & Calandruccio, 1885), its close relative *E. berlesei* (Silvestri, 1903), *E. subangusta* (Silvestri, 1903) and *E. gallii* Christian, 2009; the introduced *E. florenciae* (Rucker, 1903) is disregarded. Italy houses all of these soil dwellers and ranks first among European countries with a total of 11 palpigrade species (Harvey, 2009; updated).

Apart from one questionable record, syntopy of edaphic palpigrades in Europe has never been established. In this paper we report on a case of true co-occurrence, within one meter, of two *Eukoenenia* species. The recently described *E. gallii* is currently known only from our sampling area. *Eukoenenia mirabilis*, on the other hand, the micro whipscorpion par excellence and the first described species of this order, is

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a tramp which was widely dispersed through human activity (Harvey *et al.*, 2006), supported by its ability of parthenogenetic reproduction. The rich yield of our monthly sampling provided insights into the life cycles of the two species. Here we present the first data on the phenology of European palpigrades.

## MATERIALS AND METHODS

The study area is a *Quercus suber* plantation near Bergeggi (Province of Savona, Liguria, NW Italy: 44°15´27´´N, 08°26´35´´E), less than 500 m from the seashore, at about 150 m above sea level. Old cork-oak trees grow there on a pocket of siliceous terrain, covering a few hectares on a south-east slope within garigue and Mediterranean scrub vegetation. Ten topsoil samples, 10x10x10 cm each, were taken monthly (starting in February 2007), protected against thermal shock, and transported to Berlese-Tullgren funnels (2 mm mesh size) within a few hours. Microarthropods were extracted over at least five days (see Parisi *et al.*, 2005) into 70% ethanol.

Palpigrade specimens, partly dissected, were mounted in Marc André II medium and deposited in the following collections: BOKU Vienna, Institute of Zoology; Università degli Studi di Genova, DIP.TE.RIS.; Museo Civico di Storia Naturale "Giacomo Doria", Genova; and Muséum d'histoire naturelle de la Ville de Genève.

## RESULTS

### Gross morphology of *E. mirabilis* and *E. gallii*

The short flagellum in intact specimens gives the immediate impression that both species live in soil. The flagellum is barely as long as the trunk in *E. mirabilis*, and even shorter than the opisthosoma in *E. gallii*. Placed side by side under the stereomicroscope (Fig. 1), the two species are easily distinguished by their opisthosomal contour. The conspicuously slender opisthosoma of *E. galli* lacks the sudden constriction behind segment VIII which is seen in *E. mirabilis* and most other *Eukoenenia* species. In this respect *E. gallii* resembles the interstitial species of the genus *Leptokoenenia* (see Monniot, 1966). Life-form indices (Condé, 1998) of *E. gallii* confirm the exceedingly edaphomorphic body shape of this species (Christian, 2009).

### Phenology

Our one-year sampling period yielded a total of 145 palpigrade specimens. Two species were represented by all postembryonic developmental stages known in Eukoeneniidae. The apparent abundance of *E. mirabilis* was 2.6 times that of *E. gallii* (105 versus 40 individuals). Sex ratios (female : male; for adults and subadults) were 1 : 0.94 in *E. mirabilis* and 1 : 0.62 in *E. gallii*. Catches by month, taking into account the different instars, are presented in Fig. 2. The saisonal pattern is particularly clear in the more abundant *E. mirabilis*, and nearly identical in both species. It suggests an univoltine life cycle with the appearance of larvae in summer and subsequent dying away of the parent generation, moulting to maturity of the offspring in late September, and overwintering of adult individuals (except for a single subadult male of *E. gallii* extracted in March). Notable is the low number of palpigrades captured between December and March (*E. mirabilis*) and between November and May (*E. gallii*). The



FIG. 1
Habitus of *Eukoenenia mirabilis* (left) and *E. gallii* (right), male individuals with the flagellum broken off. For a better comparison, slightly different enlargements are shown.

majority of specimens were extracted from the mineral soil, only 7.6% (*E. mirabilis*) and 5% (*E. galli*) were extracted from the litter layer, without any apparent regularity.

## DISCUSSION

A hallmark of the palpigrade assemblage in the cork-oak plantation of Bergeggi is the presence of a bisexually reproducing *E. mirabilis* population with an evenly balanced sex ratio. Males of *E. mirabilis* are usually rare, even in samples from the presumed native range in the Mediterranean (Condé, 1984a). In fact, the first male that clearly belongs to this species was described six decades after the female (Condé, 1948). Relatively high proportions of males have been reported only from certain mainland regions (Greece: 0.39, North Africa: 0.23; Condé, 1996), whereas males are unknown, for instance, from the Canary Islands and the anthropogenic extra-European populations. It is probably not a matter of chance that parthenogenesis and spanandry prevail in subcosmopolitan palpigrades. Unisexual reproduction increases the chance of a species establishing itself after unintended introduction. The mechanism behind skewed sex ratios is not necessarily inherent, however. A wealth of evidence from other arthropods makes infection with maternally inherited "male-killing" bacteria such as *Wolbachia or Cardinium* a conceivable cause. Martin & Goodacre (2009) have shown the latter organism to be a common endosymbiont of various arachnids. Thus the

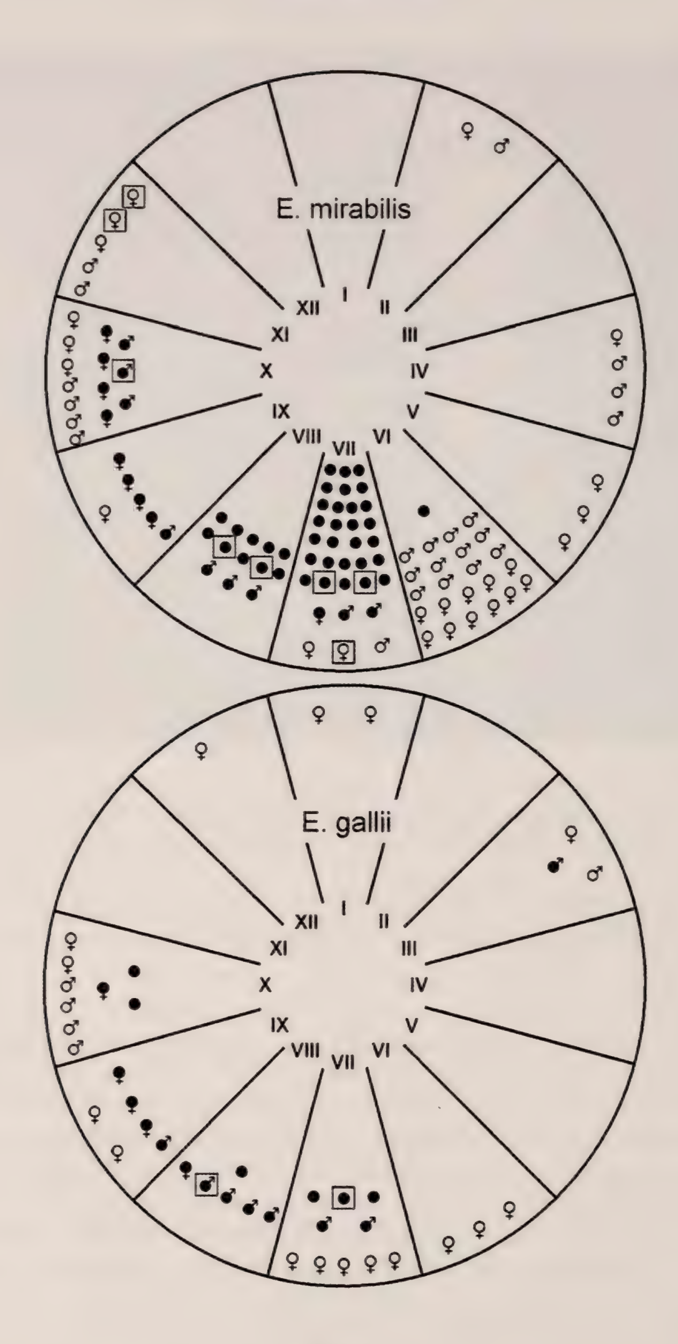



FIG. 2

Phenology of *Eukoenenia mirabilis* and *E. gallii* as inferred from monthly sampling (Roman numerals referring to the months of the year) in Bergeggi, Italy. Each symbol represents one individual. Open male and female symbols: adult individuals; filled male and female symbols: subadult individuals; filled circles: larvae. Boxes designate specimens extracted from the leaf litter.

presence of a spanandric or all-female population outside the native species range might be due to an increased bacterial load in an unfamiliar environment. Anyway, the balanced sex ratio in our samples suggests a well-adapted, native population of *E. mirabilis*.

Our phenological data, the first complete annual cycles of palpigrades from temperate latitudes, are diametrically opposed to those shown for the neotropical species *E. janetscheki* Condé, 1993. Adis *et al*. (1997) studied this very abundant soil dweller in Amazonian upland forests near Manaus, Brazil, and found the populations to be plurivoltine, without a distinct reproductive period. All instars were present the whole year round.

As to the European fauna, a unique case of repeated palpigrade observation at the same place allows a limited comparison with our results. Over many years Ressl (1995) found about 90 individuals of *E. spelaea* (Peyerimhoff, 1902) by turning over "promising" stones, half embedded in the thin soil on top of a Pleistocene river gravel deposit, at two close localities near Purgstall in Lower Austria. Since Ressl has inspected the places during various seasons, sampling bias does not fully explain why he came across the palpigrades only in April/May and September/October. It is more plausible that the typically cave-dwelling *E. spelaea* migrated downward to spend the climatically extreme seasons in the thick gravel layer. In Bergeggi we observed only a winter drop in apparent abundance, which might likewise be caused by downward migration. Another difference emerges from the data presented by Condé (1984b). The author studied 10 specimens from Purgstall, including three larvae collected on May 15 and one on September 11. Larvae, subadults and adults were coevally present in samples taken in the first half of May. This implies a blurred circannual synchronization in the Purgstall population of *E. spelaea*, as opposed to the clear univoltine seasonality of *E. mirabilis* and *E. gallii* in Bergeggi.

We know of just one reference to co-existence of edaphic palpigrade species in Europe. Georgescu & Decu (1994) reported on the occurrence of *E. mirabilis* and *E. subangusta* in a karstic environment of the southern Dobrogea, Romania. By courtesy of Eugen Niţu, Bucharest, one of us (EC) had the opportunity to examine "*E. sub - angusta*" specimens from Movile cave, including the male which had obviously been studied by the authors of the above paper. The badly preserved material revealed only a part of the diagnostic characters. Compared to the type specimen of *E. subangusta* from Italy, accurately described by Condé (1990), the Romanian animals differ slightly in the chaetotaxy of the fourth leg (Christian, 2009). Fresh material is required to assess whether the population from Romania represents a subspecies of *E. subangusta* or a discrete species. Irrespective of this taxonomic ambiguity, one may wonder whether *E. mirabilis* and the undetermined species are literally syntopic in or around Movile Cave. The sampling locations are probably close to each other, but they were not detailed by the authors.

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## REFERENCES

ADIS, J., SCHELLER, U., DE MORAIS, J. W., CONDÉ, B. & RODRIGUES, J. M. G. 1997. On the abundance and phenology of Palpigradi (Arachnida) from Central Amazonian upland forests. *Journal of Arachnology* 25: 326-332.

CHRISTIAN, E. 2004. Palpigraden (Tasterläufer) – Spinnentiere in einer Welt ohne Licht. *Denisia* 12: 473-483.

CHRISTIAN, E. 2009. A new soil-dwelling palpigrade species from Northern Italy (Palpigradi: Eukoeneniidae). *Zootaxa* 2136: 59-68.

CONDÉ, B. 1948. Sur le mâle de *Koenenia mirabilis* Grassi (Arachnides Palpigrades). *Bulletin du Muséum National d'Histoire Naturelle, Paris* (2) 20: 252-253.

CONDÉ, B. 1984a. Les Palpigrades: quelques aspects morpho-biologiques. *Revue Arachnologique* 5: 133-143.

CONDÉ, B. 1984b. Palpigrades (Arachnida) d´Europe, des Antilles, du Paraguay et de Thaïlande. *Revue suisse de Zoologie* 91: 369-391.

CONDÉ, B. 1990. *Eukoenenia subangusta* (Silvestri), Palpigrade européen méconnu. *Revue suisse de Zoologie* 97: 249-256.

CONDÉ, B. 1993. Description du mâle de deux espèces de Palpigrades. *Revue suisse de Zoologie* 100: 279-287.

CONDÉ, B. 1996. Les Palpigrades, 1885-1995: acquisitions et lacunes. *Revue suisse de Zoologie* vol. hors série: 87-106.

CONDÉ, B. 1998. Palpigradida (pp. 913-920). *In*: JUBERTHIE, C. & DECU, V. (eds.). Encyclopaedia Biospeologica, Tome II. *Société de Biospéologie, Moulis, Bucarest*, 1373 pp.

GEORGESCU, M. & DECU, V. 1994. Sur la présence de deux espèces d´*Eukoenenia* dans le souterrain et l´euédaphique du midi de la Dobrogea (Roumanie). *Travaux de l'Institut de Spéologie „Emile Racovitza"* 33: 79-84.

GRASSI, B. & CALANDRUCCIO, S. 1885. Intorno ad un nuovo aracnide artogastro (*Koenenia mirabils* [sic!]) che crediamo rappresentante d´un nuovo ordine (Microteliphonida). *Il Naturalista Siciliano* 4: 127-133, 162-169.

HARVEY, M. S. 2003. Catalogue of the smaller arachnid orders of the world. *CSIRO Publishing, Collingwood*, 400 pp.

HARVEY, M. S. 2009. Palpigradi. Fauna Europaea, version 2.1. http://www.faunaeur.org (accessed 09 Feb. 2010).

HARVEY, M. S., ŠTÁHLAVSKÝ, F. & THERON, P. D. 2006. The distribution of *Eukoenenia mirabilis* (Palpigradi: Eukoeneniidae): a widespread tramp. *Records of the Western Australian Museum* 23: 199-203.

MARTIN, O. Y. & GOODACRE, S. L. 2009. Widespread infections by the bacterial endosymbiont *Cardinium* in arachnids. *Journal of Arachnology* 37: 106-108.

MONNIOT, F. 1966. Un palpigrade interstitiel: *Leptokoenenia scurra*, n. sp. *Revue d'Ecologie et de Biologie du Sol* 3: 41-64.

PARISI, V., MENTA, C., GARDI, C., JACOMINI, C. & MOZZANICA, E. 2005. Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. *Agriculture Ecosystems and Environment* 105 (1-2): 323-333.

PEYERIMHOFF, P. DE. 1902. Découverte en France du genre *Kaenenia* [sic!] (Arachn. Palpigradi). *Bulletin de la Société Entomologique de France* 71: 280-283.

RESSL, F. 1995. Naturkunde des Bezirkes Scheibbs. Tierwelt (3). *Oberösterreichisches Landes - museum, Linz*, 443 pp.

RUCKER, A. 1903. A new Koenenia from Texas. *Quarterly Journal of Microscopical Science* n. s. 47: 215-231.

SILVESTRI, F. 1903. Descrizione preliminare di due nuove specie di *Koenenia*. *Annuario del Museo Zoologico della Regia Università di Napoli*, n. s. 1 (11): 1-2.

REVUE SUISSE DE ZOOLOGIE

Tome 117 — Fascicule 4

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Volume 117 - Number 4 - 2010

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